Instruments

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TAG Instruments

AUTOMATIC CONTROLLERS
Air-Operated
Cycle
Electric Contact
Humidity
Level
Pressure
Recording
Steam-Operated
Self-Operating
Temperature
Temperature-Time
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Vacuum

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Differential Pressure
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A. P. I.
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HYGROMETERS
Indicating
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PYROMETERS
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Indicating Controllers
Recording Controllers
Recorders—Single and Multiple Point

RECORDERS
Humidity
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Pressure
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RECORDER CONTROLLERS
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RESISTANCE THERMOMETERS
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Recorders—Single and Multiple Point

THERMOMETERS
ASTM
Chemical
Dial
Etched Stem
Industrial
Laboratory
Paper Scale
Recording

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VALVES
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Motor Operated
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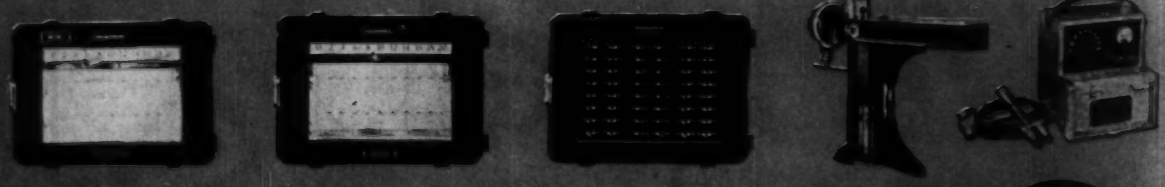

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TAG

Instruments
THE MAGAZINE OF Measurement and Control
M. F. BEHAR, Editor

Let No One Misinterpret *Instruments'* Anti-Socialism

IN spite of one confusing typographical error, our February editorial, "Instrumentation's Foe: Statism," stated the issue so clearly that no subscriber should have misinterpreted its warning. It would seem, however, that technical people are so busy these days that many of them do not read editorials carefully. Reference is not made to criticisms from sundry believers in the dictatorships which this page attacked. Reference is made to criticisms from friends—from believers in America's form of government, some of whom seem to have read between the lines various opinions which were neither implied nor intended.

Brief extracts are repeated for emphasis:

Instruments does not pretend to know more than smart radio commentators. . . . *Instruments* HOPES that this country will not drift into Statism. . . . *Instruments*, however, SEES signs that this drift is gathering momentum. . . . *Instruments* heartily approves the humane AIMS sought for . . . to lessen poverty, disease, ignorance, slums, crime and other evils. One trouble with the popular thinking of this post-war world is the weary falling back on the false philosophy that the end justifies the means, when history has proved a hundred times—and is proving today in dictator-ridden countries—that the means determine the end.

The means determine the end. Never forget that for a moment, if you wish to preserve your economic and political freedoms!

What we instrument people have today . . . isn't Utopia; it's far from perfect; nevertheless it's the best system on earth today!

Government ownership of means of production, transportation, communications, etc. . . . would transform the American system into its opposite, namely Statism. . . . Good-bye Incentive!

Government ownership of a manufacturing industry inhibits Incentive and thereby hampers progress.

Never has this page advocated that industry should take over Government functions which benefit private enterprise. Often has this page lauded the Bureau of Standards, the Bureau of Mines, the numerous Agriculture, Interior, Treasury, Justice, Army, Navy and Air Force laboratories, etc. In February, this page added the Atomic Energy Commission to the list of admirable Government activities.

So it is deplorable that a Government scientist who has been a subscriber for more than fifteen years denounces "an editorial crack at Government employees." He asserts:

Incentive does NOT go out the window when you enter Government service. Nor is it damped, diluted or destroyed by such service—that is, not unless your only incentive is to make a pile of money, and I'll venture the guess that making a pile of money has been the least of your incentives.

He mentions having received a medal and certificate for inventing what he modestly calls a "gadget" (which we must not name here because it would disclose his identity against his wish). Then he goes on:

I had not done my work for that type of reward or for any financial promotions I received; I got my satisfaction out of originating a [name of invention] . . . "Good-bye Incentive" when you work for the Government? I don't understand that; I thought I was working for M. F. Behar and tens of millions of other people. . . . We are working for IDEAS and PEOPLE. We get our satisfaction in the head and heart. Are your "incentives" any different? I'll bet not. I think you missed the nail and pounded your finger, that time.

He also accuses us of "probably" calling him and his coworkers "Bureaucrats and Government clerks."

Extracts from our reply:

. . . Editorial makes it plain that *Instruments* admires Government scientific activities . . . states explicitly that "there are increasingly large areas for central-government functions that protect and strengthen our democratic form of government."

You are right in asserting that you and other government scientists have an incentive far nobler than making money; your guess that a similar incentive rules my life is correct; that is why I do not and cannot think of you as a "bureaucrat."

You attribute to me a contempt for "most" Government workers which I do not feel as long as they are typified by you, as well as by my G-man relative and my Bureau of Standards friends at whose homes I stay when I visit Washington and who stay at my home when they visit Pittsburgh.

Perhaps you have been made hypersensitive by those who vilify "bureaucrats" in order to divert attention from selfish interests . . . vilification that has been going on for a quarter-century (I think it began when Democratic congressmen criticized the establishment of new independent agencies by Presidents Coolidge and Hoover); but you ought to know that intelligent citizens can't be fooled.

Intelligent citizens, when they use the word "bureaucrats," have in mind big-shot political appointees—officials who wield more power than is safe, who write their own "laws" and enforce them in favor of their pals and against companies or industries or segments of the population that happen to be out of favor. Probably the best presentation of the attitude of intelligent citizens toward "bureaucrats" is the series of comments on the nomination of a non-engineer to an important technical Federal Commission, printed in *The American Engineer*, organ of the National Association of Professional Engineers—a body of unquestionably intelligent citizens.

You display hypersensitiveness in accusing me of labeling most Government workers "government clerks" . . . private industry, as well as Government, is cursed with too many job-safe clock-watchers who, just once in their lives, passed an exam for a routine job protected by civil-service or company-rule or union-contract provisions and, ever since then, display no intelligence but use a sort of animal cunning to avoid getting fired. . . . There is an important difference. If a company does not extirpate these termites, it may go bankrupt; but governmental agencies—not so much Federal as city, county and state—go on and on and on. . . . Public belief that the proportion of human trash is VERY high in government agencies and VERY low in private industry. Statistics being unobtainable, the only correct opinion would be that the proportions are TOO high in both.

Instruments repeats that it sees a drift toward Statism.

This drift is accelerating. Its acceleration began with the NRA and other measures that ended the big depression; but the drift began long before that, when groups—including "rugged individualists"—asked Washington for "protection," for "security." The moment one pressure group got the laws it wanted, others joined the "gimme" chorus. Central-government "protection" and "security" cost dearly. They weaken private enterprise even when private enterprise is the "beneficiary." And when a central government makes everybody "secure," nobody is free and "government" is no longer a body of laws but a bunch of Commissars or Gauleiters over whom the people have lost control.

Instruments declares emphatically that Statism in any of its forms is your enemy because it would kill our present system of Publicly-Regulated Capitalism. We say our "present" system but the excellence of this system consists in its being constantly improved. Statism is static; our Federal Republic is a dynamic form; it is a growing organism. You are one of its rulers; under Statism you would be a slave of the State and the State would be—as in all modern dictatorships—an unholy alliance of unscrupulous big shots and gun-toting gutter gangsters.

We repeat that the danger seems remote but now we add that it is less remote than it was in February because you and you and you have not written to your Senators and Representatives that you oppose ALL Socialistic means, however good the ends may seem.

Help avert the danger by writing earnest letters to them, discussing in your own words some of the specific Socialistic measures now pending.

The Use of PNEUMATICALLY-SET INSTRUMENT COMBINATIONS

[Also known as "CASCADE" or "MULTIPLE-ELEMENT" or "INTERCONNECTED," etc.—Editor.]

By K. E. COULTER and R. W. CERMAK, The Dow Chemical Company, Midland, Michigan.

INDUSTRY at the present time has in operation a considerable number of pneumatically-set instrument combinations, such as pressure controllers resetting flow controllers, temperature controllers resetting both flow controllers and pressure controllers, etc. Such combinations allow more precise control to be attained.

A typical application where pneumatically-set instrument combinations are useful is on packed distillation columns. The control of packed distillation columns as used in commercial chemical plants and pilot plants becomes a rather difficult job when the columns are pushed to capacity and, as in many cases, when they consist of general-purpose equipment for use on a variety of different materials. In many instances, steam lines, valves, controllers and reboilers are used on a number of products and, in many cases, may be either over-size or under-size. When over-size reboilers are used on packed columns, unless precautions are taken regarding the flow of steam, the column is likely to surge, owing to a large steam input for a small period at a low rate at which fractionation is very poor.

Packed columns should be operated at all times near the flooding and loading points, as shown some years ago in the article by Smoker.* As can be seen from Smoker's work, a packed column has the maximum number of plates and maximum throughput when operated just below the flooding point, so all flows in the column should be controlled near the maximum values. As can be seen from Fig. 3, maximum capacity and efficiency exist over a very narrow range as compared to plate columns** where maximum efficiency may be obtained over a relatively wide range.

If precise control is not attained in a packed distillation column the efficiency will vary greatly and the results obtained may be discouraging.

In order to attain precise control, consideration must be given to:

(1) steam valve sizes;
(2) ranges of temperature instruments;
(3) ranges of pressure instruments;
(4) reboiler sizes;
(5) temperature differences between steam and material being vaporized; and
(6) the over-all heat transfer coefficients on the reboiler.

Of the above-mentioned, only steam valve sizes and selection of instruments and ranges as well as temperature difference across the reboiler can be varied, all other factors being fixed for any installation.

*E. H. Smoker, *Trans. A.I.Ch.E.*, Vol. 40, 1944, No. 1, pages 105-116.

**G. G. Brown and F. J. Lockhart, *Trans. A.I.Ch.E.*, Vol. 39, 1943, No. 1, pages 63-75.

In the operation of distillation columns, the factor to be controlled is the composition of the products leaving the top and bottom of the unit. To control composition some variable must be measured in the column which can be interpreted in terms of composition and used for control purposes. A few variables which may be measured are temperature, refractive index, thermal conductivity, dielectric constant, specific gravity, etc. For the particular case to be illustrated, the assumptions have been made that temperature is the variable and that the temperature gradient in the column is sufficiently great for satisfactory operation of the temperature controller.

FIG. 1

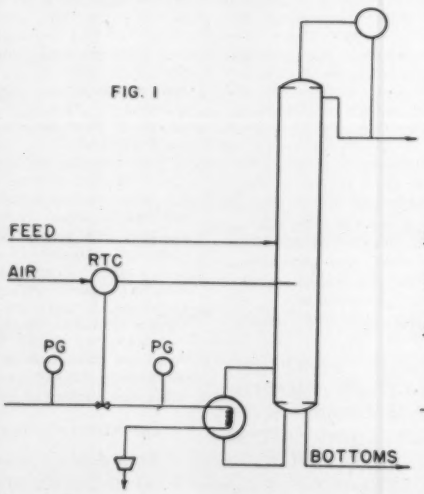
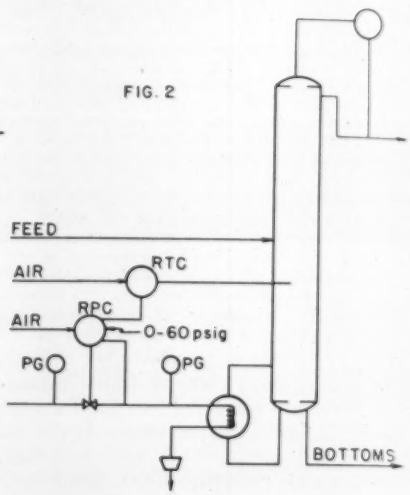


FIG. 2



An example of how the above should be taken into consideration is best shown by the solutions of the following problems:

I.—Where the steam to the reboiler is controlled directly by a temperature controller having its temperature point in the column. (See Fig. 1.)

II.—Where the steam to the reboiler is controlled from a temperature point in the column, using a temperature controller resetting a steam pressure controller. (See Fig. 2.)

The following conditions and sizes exist in both cases:

(1) Measured over-all heat transfer coefficient on reboiler, 135 Btu. per hr. per sq. ft. per deg. F. difference.

(2) Area of heating surface in reboiler, 120 sq. ft.

(3) Latent heat of vaporization of material in reboiler, 140 Btu. per lb.

(4) Normal vaporization rate, 2400 lbs. per hour.

(5) Btu. transferred per hour per deg. F. change in temperature difference between steam and material in the reboiler (135 times 120), 1620. Or, 117.5 lbs. per hour are vaporized per deg. F. change between steam and material in the reboiler.

(6) Only one component exists in the reboiler.

(7) Normal reboiler steam pressure, 40 psig.

SOLUTION OF FIRST (Fig. 1) PROBLEM

Investigation of the effect of steam valve sizes between maximum and minimum recommended pressure drops across the valve as shown in Fig. 1:

2400 times 140 equals 336,000 Btu. per hr. normal heat transfer rate.

Latent heat of vaporization of steam equals 920 Btu. per lb.

336,000 over 920 gives 365 lbs. of steam per hour.

Pressure upstream of valve, 95 psia;

Pressure on reboiler, 55 psia;

Pressure difference, 40 psi.

Equivalent valve size (from Foxboro slide rule), 0.563 in. Since this is an odd size, use a three-quarter-inch valve having a maximum capacity of 700 lbs. of steam per hour.

Percent of total flow at normal vaporization rate, 365 over 700, times 100, equals 52.2.

From valve characteristic curve (Fig. 4), valve is 84 percent open.

Standard air-to-open valve is closed at 3 psi diaphragm pressure and open at 15 psi corresponding to a pressure change of 12 psi on the diaphragm of the valve. To open control valve 84 percent requires 0.84 times 12 plus 3, or 13.1 psi applied to diaphragm.

Temperature recorder-controller chart range is 0-200 deg. C. Chart width is 4.6 inches. Degrees C. per inch of pen movement, 200 over 4.6, or 43.5 deg.

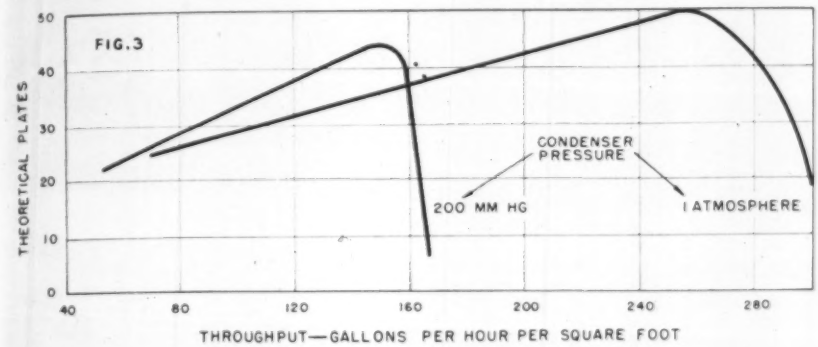
Using a control sensitivity setting of

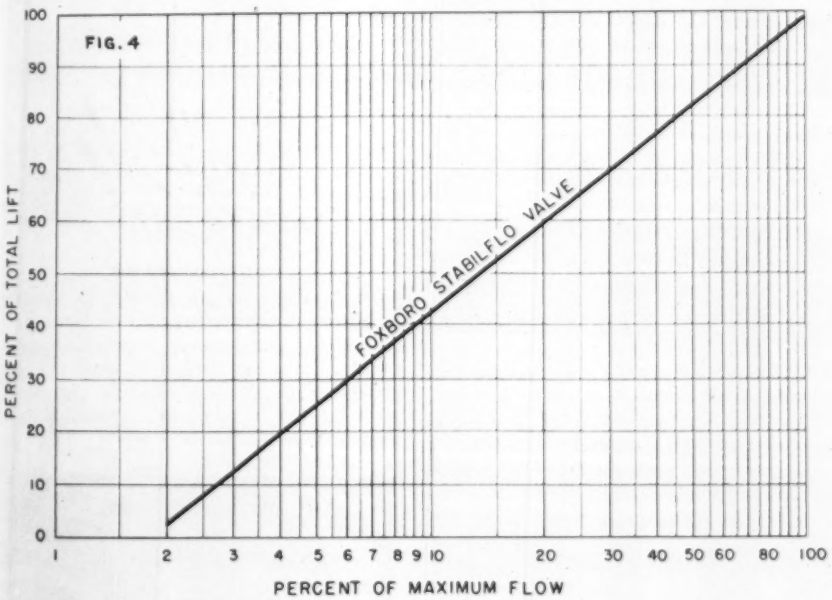
"20," corresponding to 20-psi change in air pressure to control-valve diaphragm per inch of pen movement, we get 43.5 over 20, or 2.17 deg. per psi change in output pressure.

Let us assume a temperature change of 2.17 deg. C. or an output air pressure change of 1 psi. Air pressure on diaphragm is now 13.1 plus 1 or 14.1 psi and the valve is (10.1 plus 1) over 12, or 92.5 percent open, and (again referring to Fig. 4) is passing 73 percent of its total flow, which is 700 times 0.73, or 511 lbs. per hour.

511 times 100 over 365 equals 140 percent of original or 40 percent increase in vapor rate up the column.

New vapor rate up the column is now 1.40 times 2400 or 3360 lbs. per hr. as compared to 2400 under normal conditions.





Recalculate with less pressure drop across the valve:

Upstream pressure, 60.5 psia;

Downstream pressure, 55 psia;

Differential, 5.5 psi.

Valve size, from slide rule, 0.875 in. Use a 1-in. valve with a maximum rate of 460 lbs. per hour.

Percent of valve capacity, 365 times 100 over 460, or 79.5 percent, corresponding to valve opening of 94 percent.

12 times 0.94 equals 11.3, plus 3 equals 14.3 psi on valve diaphragm.

With a control sensitivity setting of "40," a 1.085 deg. C. temperature drop causes a 1 psi increase in output air pressure to valve diaphragm. The valve now has 14.3 plus 1 or 15.3 psi air pressure on its diaphragm and is wide open.

When temperature drops 1.085 deg. C., the vaporization rate becomes 460 times 100 over 365, or 126.01 percent of original, which is an increase of 26.0 percent.

New vapor rate becomes 1.26 times 2400 or 3020 lbs. per hour as compared to 2400 under normal operation.

Solution of Second (Fig. 2) Problem

As shown above, the maximum and minimum pressure drops across the valve give 53.5 percent and 26.0 percent increases in vaporization rates, which are still too large. Let us now recalculate, using the control scheme in Fig. 2 with ranges and control settings as shown.

Instrument charts are 4.1 inches wide and control sensitivity is set at "5" on a 0-60-psig. instrument. Pneumatic setting mechanism on pressure controller moves control index 0.025 inch per psi change in output air pressure from the temperature controller.

Change in steam pressure per inch of chart, 60 over 4.1, or 14.6 psi.

Assume as before a 1.085 deg. C. drop in temperature on the temperature controller, which causes the following:

(1) Change in output air pressure from temperature controller, 1 psi.

(2) Pneumatically-set control index in pressure controller moves 0.025 inches, corresponding to 14.6 times 0.025 or 0.365 psi change in steam pressure setting.

(3) With pressure controller sensitivity at "5," output air of pressure controller or air to control valve diaphragm changes 0.025 times 5 or 0.125 lbs.

(4) Air pressure on diaphragm of 1-in. valve is 3 plus 11.3 plus 0.125, or 14.425, or valve is 95.5 percent open.

Under these conditions the steam pressure in the reboiler has increased from 54.7 to 55.065 psia or the temperature has changed from 286.72 deg. F. to 287.17 deg. F. or 0.45 deg. F. The change in heat transfer rate is then 16,200 times 0.45 or 7290 Btu. per hour, which causes an increase in vaporization rate of 7290 over 140, or 52 lbs. per hour. An increase of 52 lbs. per hour in vaporization rate is an overall increase of 2.1 percent. This small change is in sharp contrast to the 53.5 percent and 26.0 percent changes previously determined. In addition, it illustrates the advantages to be obtained by the use of pneumatically-set instrument combinations where the ultimate in close control is required.

After following through on these examples, it may be well to re-examine the process-equipment factors which could vary the operation. They can be listed as follows:

(1) The heat transfer surface in the reboiler;

(2) The over-all heat transfer coefficient;

(3) The latent heat of vaporization of the material in the reboiler.

An illustration of the above could be with the reboiler containing 240 square feet of surface, in which case the vaporization rate increase would be double the ones presented; or, if 60 square feet were used, the variations would have been one-half the values quoted.

The same would hold for a two-fold increase in over-all heat transfer coefficient or a 50 percent decrease.

If the latent heat of vaporization of the material in the reboiler were 900 Btu. per lb. instead of 140, the variations would have been 15.8 percent of the values quoted.

Thus it is obvious that these two factors, one-half as much heat transfer surface and a latent heat of vaporization of 900, could combine and make the use of the pneumatically-set instrument combination unnecessary.

The authors realize that with the valve sizes and instruments as shown in Figs. 1 and 2, a large number of settings may be made and various vaporization rates obtained. The illustrative problems were given to show the effect of instruments and instrument combinations and also equipment sizes on the control conditions which can be expected.

Fig. 1

Instrumentation *for* Flight Testing *the* XB-45 Airplane

By D. K. WARNER, Supervisor of Flight Test Instrumentation,
North American Aviation, Inc., Los Angeles, Calif.

Introduction

NORTH AMERICAN AVIATION is currently delivering one hundred and thirty-nine B-45 bombers to the Air Forces, where they are scheduled for tactical service with the 47th Bomber Wing at Barksdale Field, Louisiana. Back of this highly-successful light-bombardment jet-powered airplane (see Fig. 1) lies nearly two years of exhaustive testing of the prototype, the XB-45. In view of the fact that the XB-45 was the first airplane of its type ever to be flown, it was extensively instrumented to provide engineering information on all phases of its operation.

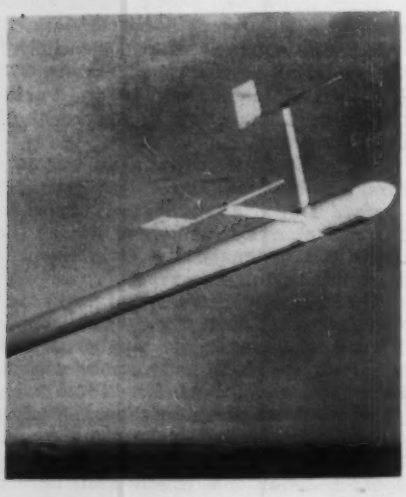


Fig. 2

General

Purpose of the instrumentation installed in this airplane is to furnish recorded data on the following four general items of quantitative information:

1. Airplane Performance
2. Engine Performance
3. Airplane Stability and Control
4. Structural Strains and Stresses

To record all these data, the following automatic recording instruments are installed in the airplane:

1. Five photo-recorders (sometimes referred to as automatic observers), which record the readings of a total of 120 separate instruments.

2. One triple-range Leeds & Northrup automatic recording pyrometer potentiometer, which records temperatures at 140 different locations.

3. Three Consolidated Engineering Co. 14-channel recording oscillographs, which record structural strains at various selected locations in the airplane.

The installation of all these instruments necessitated several changes in the external configuration of the airplane. Supplementing the standard source of total-head ram pressure and static pressure for measurement of airspeed and altitude are a swivelling Pitot-static head on the end of a boom and also a trailing static bomb which is lowered on a length of hose below the airplane. The boom on which the swivelling Pitot-static head is mounted extends forward from the left wing-tip. A multiple-shielded outside air temperature pick-up is mounted under the left wing tip. A double-vane device to pick up angle-of-yaw and angle-of-attack is mounted on the end of a similar boom which extends forward from the right wing-tip (see Fig. 2).

Photo-recorders

Photo-recorder number 1 is located in the nose section of the airplane and has space for sixteen aircraft instruments. It is so designed that the instrument panel is visible to the occupant of the bombardier's seat, should observer personnel be desired. This re-

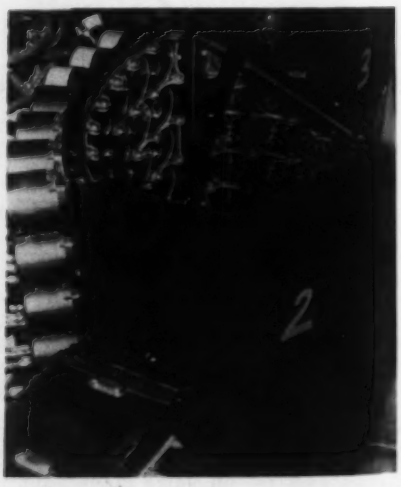


Fig. 3

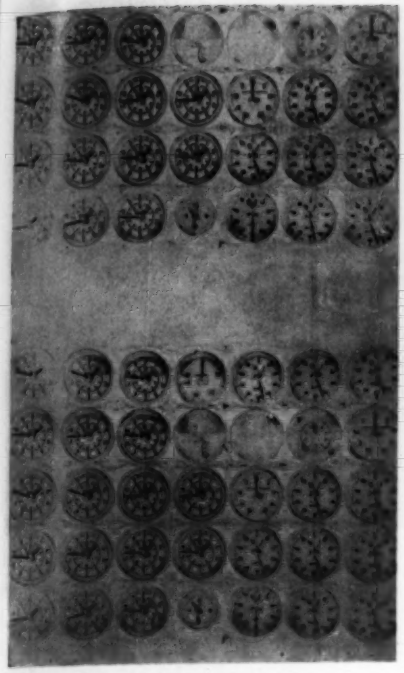


Fig. 4

Fig. 5

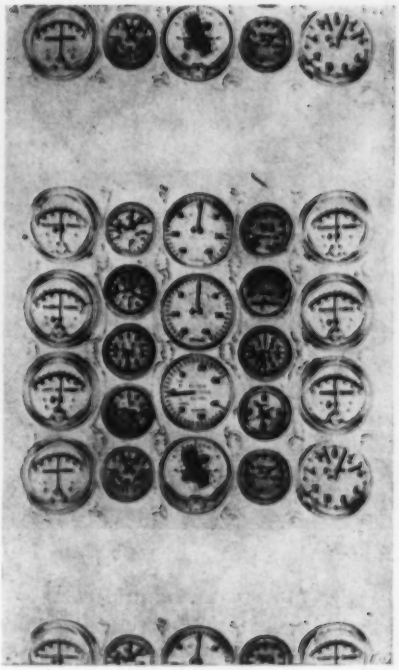


Fig. 6

corder uses a camera which has a capacity of 400 feet of 35-mm. film. Photo-recorders numbers 2, 3, 4 and 5 are located in the fuselage, aft of the bomb-bay. These are all enclosed photo-recorders, as no observer personnel occupy this part of the airplane. Recorders 2, 3, and 4 use cameras which are identical with the camera used in the number 1 recorder. Recorder 2 and 3 each have space for thirty-five aircraft instruments, and in each of these recorders a mirror is used to permit an over-all reduction in the size of the recorder. Photo-recorder number 4 has space for twenty-two instruments. Photo-recorder number 5 has space for 12 aircraft instruments and uses a Bell and Howell 16-mm. magazine-loading camera which has been equipped with an electromagnetic actuator. In each of these recorders, the camera is mounted on adjustable rails to permit exact camera alignment with the recorder-panel, and the solenoid actuating mechanism is accessible for inspection and adjustment without removing the camera from the recorder. Fig. 3 shows one of the recorders installed in the airplane, and Fig. 4 shows a typical sample of film from this recorder.

The instruments mounted in photo-recorder number 1 include three air-speed indicators which are connected to three separate Pitot-static sources, three altimeters connected to three separate static pressure sources, an air temperature indicator, four counters which indicate the fuel-flow in gallons to each of the four engines, four tachometers which indicate the turbine R.P.M. in each of the four engines, and a standard aircraft clock. The data from this recorder are primarily used for evaluating airplane performance, but are also required in part for other types of flight testing.

Photo-recorders 2 and 3 contain instruments which give the necessary data for evaluating engine performance. To avoid unnecessary duplication, the left inboard engine was instrumented most fully, and only enough instrumentation was installed on the other three engines to permit over-all performance determination and correlation of data with the complete data recorded on the left inboard engine.

Airspeed indicators are used to measure the flow of air into the compressors of the engines. These pressures are separately picked up from three separate points on each of four symmetrically-located rakes in each of the four inlet ducts, as shown in Fig. 5. Airspeed indicators are also used to measure the flow of cooling air to the various parts of the engines and engine nacelles. The pick-ups used for these pressures are similar to those used in the inlet ducts.

Sensitive-reading manifold pressure gages are used to measure the flow of exhause gas in the tail-pipes of the engines. These instruments cover a range of ten to two hundred inches of mercury, absolute. The large pointer makes nineteen complete revolutions in covering the full pressure range of the instrument, and there are one hundred dial graduations for each revolution. In other words, the complete pressure range of the instrument is graduated into nineteen hundred parts, thus providing excellent readability. The pressures indicated by these instruments are picked up by stainless-steel rakes mounted in the tail-pipes.

Other pressure gages are provided to measure primary and secondary fuel pressure, control oil pressure, and fuel pressure into the engine fuel pumps.

In order to avoid loading down the standard source of static pressure on the airplane with an excessive number of instruments, a reference static pressure chamber is installed in the airplane to which some of the power-plant performance instruments are connected. This chamber is in turn referenced to the standard static pressure source, and this reference pressure is indicated by a differential pressure gage.

The main purpose of photo-recorder number 4 is to furnish recorded airplane stability and control data. This photo-recorder contains microammeters which are connected to the output of strain-gage bridges to measure control forces, an accelerometer which measures vertical acceleration, gyro instruments which indicate rate-of-yaw, rate-of-roll, rate-of-pitch, and airplane attitude. With the exception of the standard aircraft clock, all the remaining instruments in this recorder indicate angular displacements of flight controls and their trim tabs. Fig. 6 shows a sample of film from this recorder.

All the instruments in photo-recorder number 5 indicate deflections at various locations in the airplane. The transmitter units which are connected to these indicators are all geared d-c. Selsyn transmitters equipped with lever arms and actuating links.

In measuring aileron, elevator, and rudder angles, the desired degree of accuracy could not be obtained by using single pointer indications. Accordingly, special Selsyn transmitter units were constructed which actually contained two separate Selsyn transmitters, one being geared to rotate at four times the speed of the other. A pulley is attached to the operating shaft of one of the Selsyn transmitters and this in turn is connected to the airplane control system by means of a flexible braided steel cable. The pull exerted on this cable rotates the pulley in one direction and a helical spring within the Selsyn transmitter unit rotates the pulley in the opposite direction. The direct-drive Selsyn transmitter and the transmitter that is geared four-to-one are separately connected to the two Selsyn indicator mechanisms of a dual Selsyn indicator. Thus, one pointer on the indicator makes four complete revolutions for one revolution of the other pointer, thereby providing four times the precision that would otherwise be obtained.

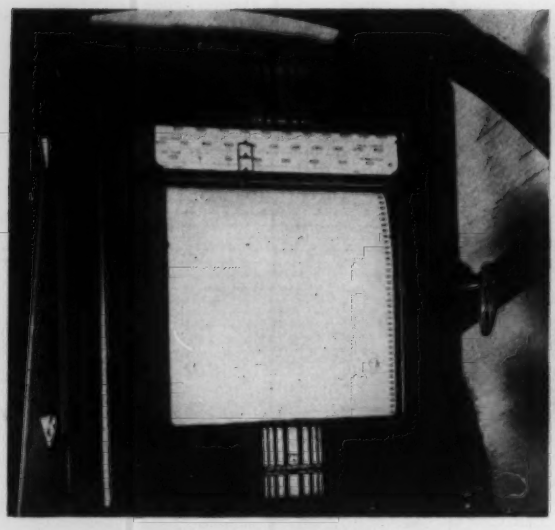


Fig. 7

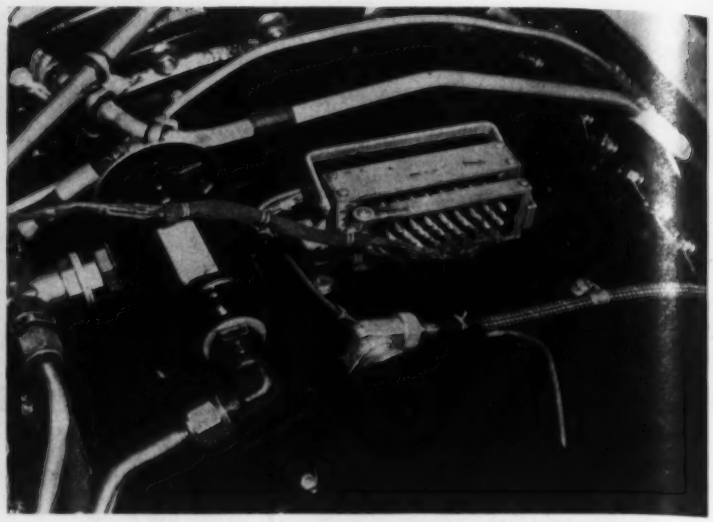


Fig. 8

Special Pilot's Instruments

In addition to the instruments which are photographed in the five photo-recorders, specially-calibrated test instruments were installed in the pilot's and co-pilot's instrument panels to permit these persons to accurately read airspeed, altitude, acceleration, angle-of-attack, angle-of-yaw, engine exhaust temperatures, engine bearing temperatures, and Mach number.

Temperature Recorder

The recording pyrometer is installed in the nose section of the airplane, with the chart paper visible to an observer sitting in the bombardier's seat, as shown in Fig. 7. The box containing the stepping switches and circuit selectors is mounted on the floor just to the right of the bombardier's seat.

The recorder is set up to record a total of 120 separate temperatures as picked up by iron-constantan thermocouples and 20 separate temperatures as picked up by chromel-alumel thermocouples. Automatic reference-junction compensation is provided in the potentiometer circuit, eliminating the need for reference ice bottles. Included in the list of temperatures measured by iron-constantan thermocouples are bearing temperatures, outside air temperature, fuel temperature, compressor air temperatures, and the temperatures existing at various points in the airplane structure in the vicinity of the engines. Temperatures measured by chromel-alumel thermocouples include temperatures at two different points in each of the four tailpipes and temperatures in each of the burners in the left-hand inboard engine. To facilitate engine removal, multiple-point thermocouple line disconnects are installed on each of the four engines, as shown in Fig. 8.

Structural Instrumentation

A total of 158 separate strain-gage bridges are installed throughout the airplane for measuring structural stresses and strains. Of this total, 81 are in the wings, 24 in the fuselage, 21 in the horizontal stabilizer, 13 in the vertical stabilizer and 19 in the left engine nacelle, as illustrated in the accompanying diagram, Fig. 9.

The Baldwin-Southwark Type SR-4 strain gages used in this installation are wire grids that undergo a slight change in electrical resistance when stretched or compressed. When they are employed as arms of a Wheatstone bridge, the amount of unbalance of the bridge bears a definite relation to the amount of strain to which the gage is subjected.

Separate multi-conductor cables run from each of the 158 strain-gage locations to a terminal board located on the aft side of the rear bomb-bay bulkhead. At this point each of the cables is terminated in a four-conductor electrical disconnect (see Fig. 10). Three 14-channel Consolidated Engineering Co. recording oscillographs and their associated bridge-balance units are installed in the rear fuselage section of the airplane; these permit simultaneous recording of any thirty-six of the total of 158 separate strain-gage bridges. The three bridge-balance units, each having twelve separate channels, are mounted on top of each other; and thirty-six separate cables from these units connect to the selected points on the strain-gage terminal board, as shown in Fig. 11. No amplifiers are used in this strain recording system, as sufficient output is obtained from the strain gages to permit unamplified direct-current operation of the recording galvanometers.

Owing to the fact that separate isolated sources of electric power are required to operate the recording oscillographs and to provide the necessary voltage on the strain-gage bridges, it was necessary to install additional storage batteries in the airplane. These are located in the tail section of the fuselage just aft of the rear entrance hatch. Two 24-volt batteries connected in parallel provide the voltage for the strain-gage bridges; and four 12-volt batteries connected in parallel operate the three recording oscillographs.

Instrumentation Controls

Controls to operate the instrumentation installed in this airplane are located in the cockpit of the airplane.

The pilot is provided with a master switch, individual switches for each photo-recorder, a switch to start and stop the operation of the recording pyrometer, and a switch to start and stop the operation of the three recording oscillographs.

A switch is provided to enable the pilot to select either single-picture exposures in the photo-recorders or cyclic exposure at the rate of four pictures per recorder per second; and two momentary-contact switches operate the cameras in the photo-recorders. One of these switches is mounted on the pilot's control wheel and its operation causes the selected photo-recorder cameras to photograph the lighted instrument panels in the recorders. Operation of the second switch turns out the lights in all the recorders and also actuates the cameras; this produces an unexposed frame on the recorder film and is used to identify the beginning and end of separate test runs.

Two controls are provided for the control-force measuring instrumentation; one of these is a master switch and the other is a momentary-contact calibration switch. Operating this switch places an unbalancing resistor across one arm of each force-measuring bridge, and the electrical value of these resistors is such that they produce deflections in the indicating microammeters which are identical with those which would be produced by known amounts of force on the control systems. Thus, it is possible to correct the recorded data for any variation in battery voltage which might take place in the course of a flight.

Recorded Data

The films from the photo-recorders are processed as photographic negatives, and the negative pictures of the recorder panels are read one frame at a time in Recordak film readers. The

chart from the recording pyrometer is graduated in one hundred uniform divisions, and separate calibration curves are provided to the personnel of the Data Reduction Section for determining the temperatures recorded in both the high- and low-temperature ranges. The records from the recording oscillographs are processed photographically and the deflections of each of the traces on the oscillograph records are measured with the aid of a special oscillograph record reader instrument which was developed for the purpose by North American Aviation.

In actual use, all the instrumentation in the airplane is seldom operated at any one time. However, the actual quantity of recorded data which all the instrumentation operating simultaneously is capable of turning out is rather amazing. With all five photo-recorders operating at a cyclic rate of four pictures per second, the three oscillographs each operating at a paper speed of eight linear inches per second, and the recording pyrometer printing one temperature every 1.63 seconds, just one minute of continuous operation provides thirty-seven separate temperature recordings, one thousand four hundred and forty linear inches of oscillograph records, and twelve hundred separate photographic pictures of instruments which show a total of twenty-eight thousand eight hundred individual instrument readings.

NORTH AMERICAN AVIATION, INC.
B-45 AIR FORCE JET BOMBER

Crew or number seats: Four

Dimensions

Span: 89 ft. 6 in.
Length over-all: 74 ft.
Height over-all: 25 ft.

Wings

Spar: Aluminum
Ribs: Aluminum
Covering: Aluminum

Landing Gear

Type: Hydraulically retractable
Tread (in.): 267
Wheel type and size—main gear: 64 in — 64 × 19-30 in. high-pressure tire
Brake: Bendix Rotor-disk hydraulic
Loading gear shock unit: Bendix RxB, 7332 air-oil
Nose gear: Hydraulically retractable

Power Plant

Make of engine: (4) General Electric-Allison J-47 (TG-190)
Static thrust: 20,000 lbs. (5000 lbs. each engine)
At altitude, ft.: Sea level

Performance

High speed: In 550 m.p.h. class
Normal range: Tactical radius more than 800 miles
Service ceiling: Over 40,000 ft.

Weights

Gross weight: 82,600 lbs.
Wing loading: 70.3
Bomb load: Over 10 tons
Production: One hundred and thirty-nine B-45's have been delivered or are on order for the Air Force.

View of the XB-45 showing some of the structural members and some approximate locations of strain gages. (Details lost in the reduction are unessential.)

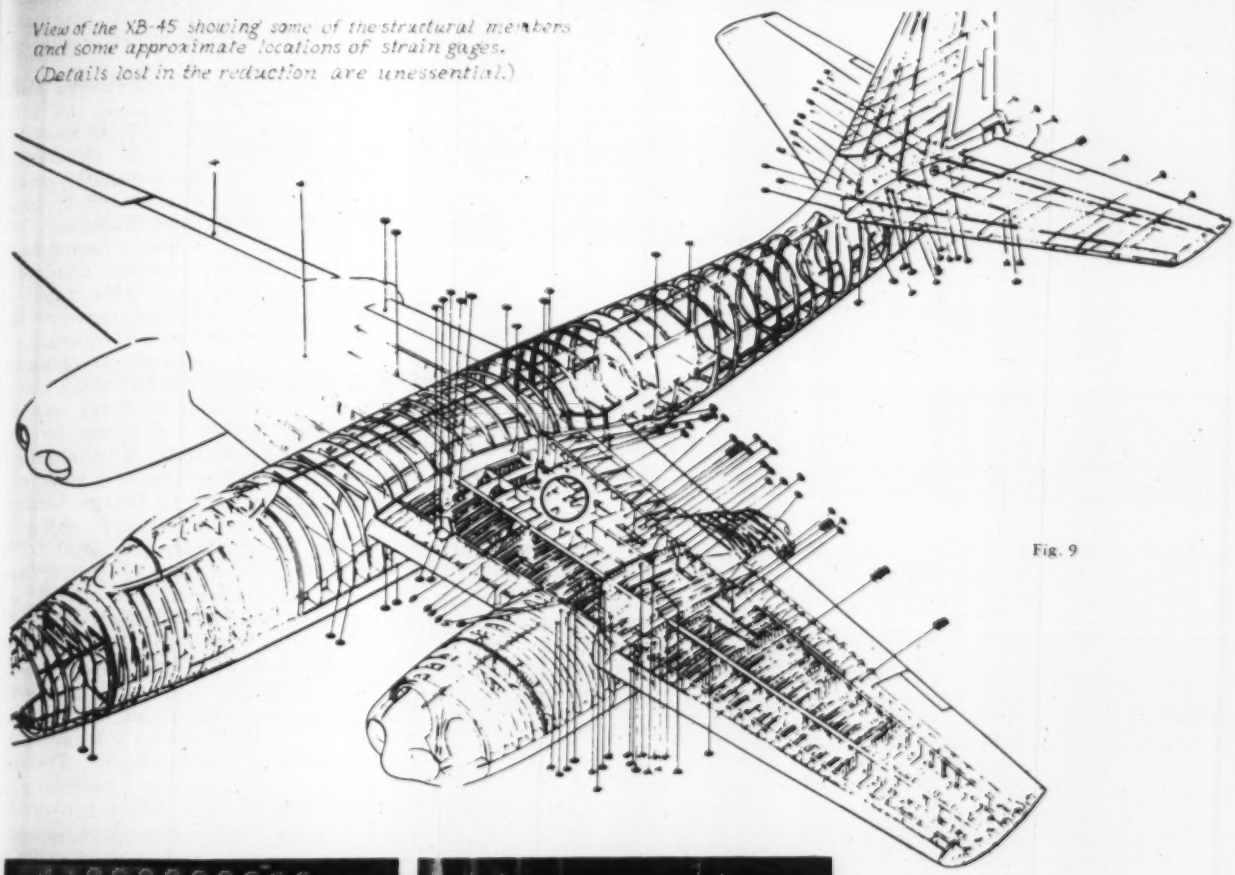


Fig. 9

Fig. 10

Fig. 11

A Primary High-frequency Voltage Standard

By MYRON C. SELBY, Central Radio Propagation Laboratory,
National Bureau of Standards, Washington, D. C.

RECOGNIZING the importance of high-frequency standard voltage in the calibration and adjustment of many types of instruments, the National Bureau of Standards is developing primary standards of voltage for radio frequencies up to several hundred megacycles. This work is being carried on in the Bureau's Central Radio Propagation Laboratory as part of a broad program to develop national standards for electrical magnitudes at all radio frequencies.

Precision voltage standards are urgently needed by communications services and research groups in the adjustment of many laboratory and field instruments operating at high frequencies. The calibration of signal generators, field-intensity meters, radio receivers, and vacuum-tube voltmeters depends on the accuracy of available reference standards.

A practical high-frequency voltage standard must combine reliability with maximum precision and should approach as closely as possible the accuracy of the direct-current voltage standard—the standard cell. With this in mind, the Bureau has concentrated on methods of measuring single-frequency voltages directly in terms of a standard d-c. cell. Specific techniques have been chosen for best time-efficiency and accuracy over the widest range of voltage and frequency, without using frequency corrections. Reliability has been achieved by cross-checking the results of several independent methods based on different principles. Reproducibility of results and agreement between individual primary-standard methods is required within plus-or-minus one percent, since measurements to that accuracy are considered to be of good precision in the h-f. region.

One of the techniques developed by the Bureau which satisfactorily meets the basic requirements for a primary standard is the voltage-measuring bolometer bridge (a modification of the better known radio-frequency power-measuring bridge), utilizing the dependence of bolometer resistance on power dissipation. In this method, a d-c. bridge with a bolometer in one of its legs is first balanced on direct current. R-f power is then substituted for some of the d-c. power and the bridge is rebalanced. The amount of r-f. power equals the difference in d-c. power required for balance in each case.

In the application of the bolometer to h-f. voltage measurements, the reactive component of the bolometer impedance must be known, although it has no bearing on the accuracy of h-f. power measurements. For that reason, in h-f. voltage measurements the bolometer impedance configuration must be accurately known, and the d-c. voltage across the bolometer should equal the rms. value throughout the required frequency range. This condition can be met only if the bolometer admittance consists effectively of pure conductance shunted by an incidental reasonable value of positive or negative susceptance.

Several major developments made possible the application of the bolometer bridge to h-f. voltage measurements. A type of bolometer remarkably suited to the job was fortunately available in the form of microscopically-small thermistors (0.015 inch diameter). The careful design of a special mount for a two-thermistor arrangement eliminates frequency corrections. This type of mount reduced the temperature-time lag of the thermistors and consequently reduced the time required to obtain a bridge balance. Special switching, shorting, and interlocking circuitry was developed to replace r-f. power by d-c. power instantaneously. This arrangement provides for extremely close and frequent checking of bridge balance with and without r-f., largely eliminating interference from incidental drifts of ambient temperature and d-c. voltage sources. In addition, this circuit arrangement allows maximum precision in the measurement of extremely small increments of large d-c. voltage values.

The thermistor bridge has been used so far in the voltage range from 20 millivolts to 1.5 volts at all frequencies from audio to 800 megacycles. The top frequency limit may be considerably higher, but this limit will not be established until other independent methods

Fig. 1. The new primary radio-frequency voltage standard developed by the NBS makes available high-precision voltages without any frequency corrections. It consists of a voltage-measuring thermistor bridge, a special thermistor mount, instantaneous and simultaneous r-f./d-c. switching arrangement, a d-c. voltage source stability of the order of 1 part in ten million per minute, and d-c. measuring circuitry with a sensitivity of 1 part in ten million (measurement accuracy of 1 part in 100,000 to 1 percent). The equipment is shown in an experimental arrangement, with the thermistor mount and coaxial switch at left.

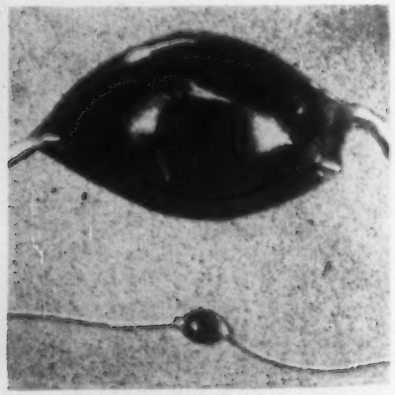


Fig. 2. Two thermistor beads, shown in a 15-to-1 magnification. The maximum diameter of the smaller bead is about fifteen thousandths of an inch. Its wire leads are one-thousandth of an inch in diameter: they appear as white lines above their gray-line shadows.

are available at the higher frequencies. In the region from 200 Mc. to 800 Mc., the thermistor bridge was checked against power measurements based on the voltage distribution along a slotted transmission line. The accuracy of the data in this frequency range is limited by the inadequate precision (about plus-or-minus 5 percent) of the slotted transmission lines available at present. Up to 200 Mc., several independent methods—cathode-ray oscilloscopes, thermoelements, and electrostatic voltmeters—agreed to within 1 percent. The higher voltage range was extended to 10 volts in the frequency range up to about 50 Mc. by using thermistor beads of a considerably larger diameter.

Extending the lower limit of standard voltage to the millivolt range makes possible more accurate voltage determinations with the help of standard attenuators in the critical microvolt region. Because of imperfections in attenuators for VHF and UHF applications, a more accurate microvolt may be realized by using a standard millivolt and a 60-decibel attenuator rather than a standard volt and a 120-decibel attenuator. For that reason, the Bureau is attempting to obtain as low a standard voltage as possible. The attenuation of standard attenuators may be measured directly in terms of voltage ratios, a very useful technique in cases where attenuator input power must be kept low.

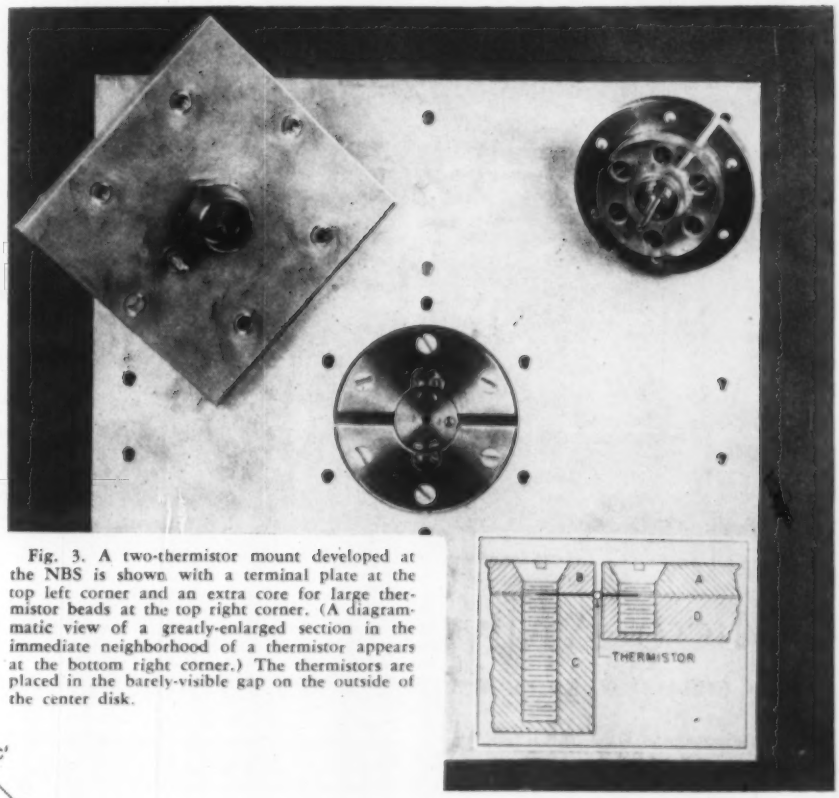


Fig. 3. A two-thermistor mount developed at the NBS is shown with a terminal plate at the top left corner and an extra core for large thermistor beads at the top right corner. (A diagrammatic view of a greatly-enlarged section in the immediate neighborhood of a thermistor appears at the bottom right corner.) The thermistors are placed in the barely-visible gap on the outside of the center disk.

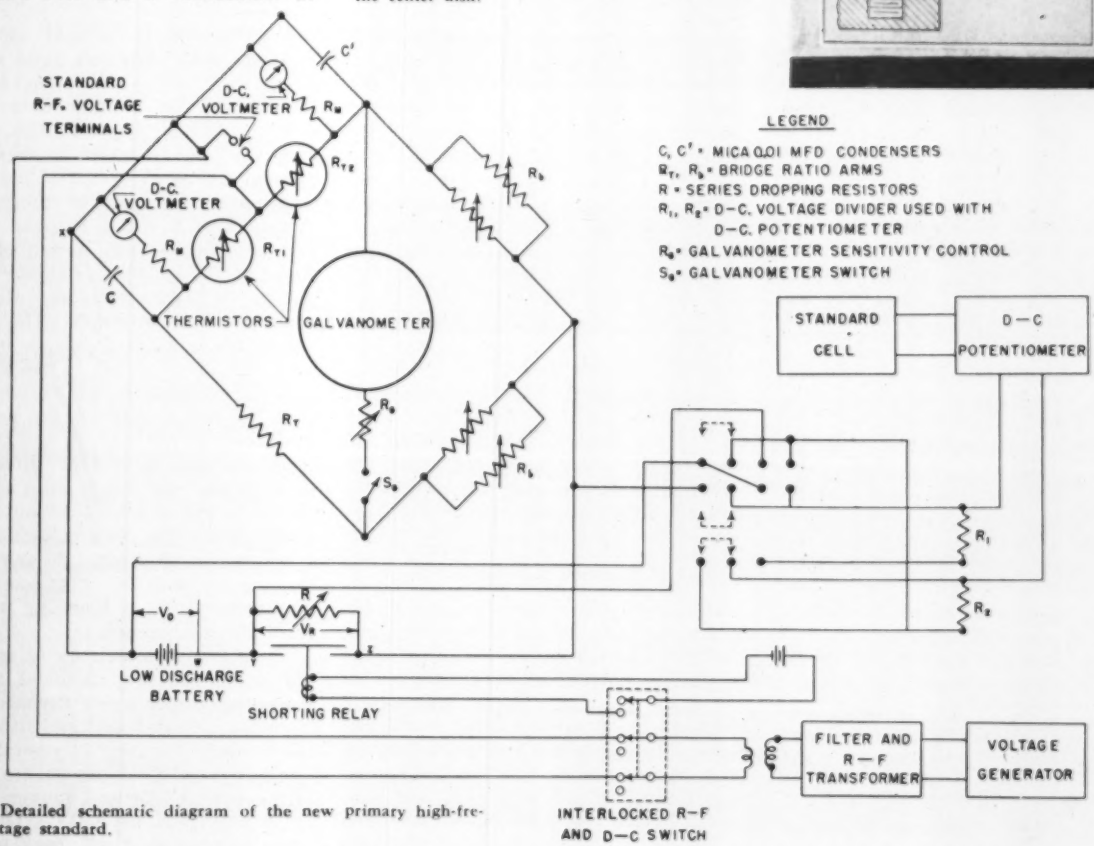
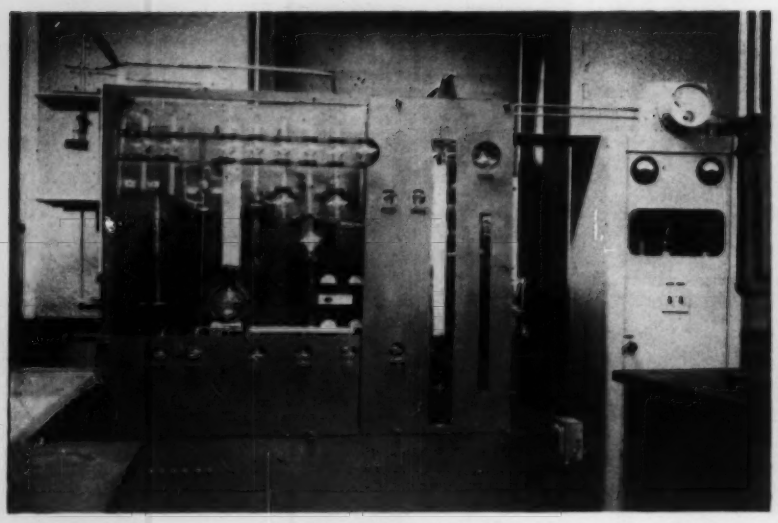
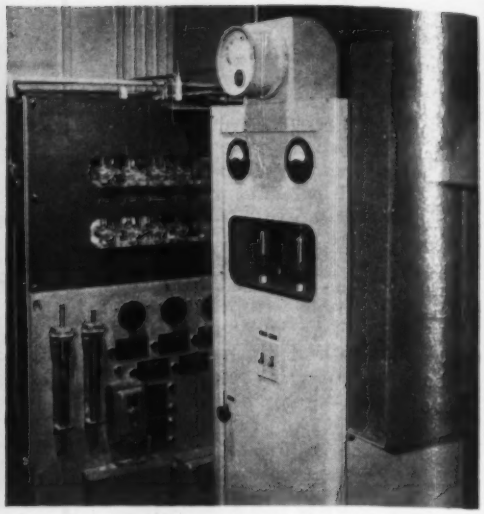


Fig. 4. Detailed schematic diagram of the new primary high-frequency voltage standard.

Individual factors limiting voltage accuracy have been analyzed and correlated with voltage range. These include effective thermistor sensitivity, bridge sensitivity, stability of the d-c. voltage supply, irreducible voltage drops in the circuit, thermal voltages, and ambient temperature variations, as well as limitations in measuring d-c. voltages and the resistance of bridge elements.

The low voltage limit measurable with a total accumulated error of 1 percent has been evaluated by assuming a possible 0.1 percent contribution from individual factors; the computed low voltage limit agrees closely with the experimental value. Mounting a large number of thermistors in a series parallel circuit promises to reduce this low limit still further. Connecting the thermistors in parallel for r-f. and in series for d-c. balancing produces low over-all r-f. resistance and voltage without sacrificing d-c. precision.





(Left) Front view of micro gas analysis unit. *(Right)* Analytical section and r-f bombarder.

Micro Analysis *of* Gases Evolved *from* Metals

By GERALD W. KEILHOLTZ and MARTHA J. BERGIN, Sylvania Electric Products Inc., Salem, Mass.

IN the electronic tube industry, vacuum plays a major role. To assure constancy of the vacuum throughout the life of the numerous tubes, lamps, etc., all metals used therein must be investigated as to their performance under operating conditions—especially the rates and amounts of gases evolved from these metals — which is of the greatest importance.

In studying methods by which tube performance could be improved, a gas analysis unit was designed to explore this characteristic so that metals may be evaluated without the necessity of testing by actual operation in the tubes. In this article the degassing of a series of commonly-used metals will be the principal application considered. These metals include nickel, carbonized nickel, nickel-plated steel, oxidized nickel-plated steel, steel, blackened steel, and aluminum-clad steel. The effect of the type of processing on the amount and kind of gas evolved upon heating of each metal are discussed herein.

The gas analysis unit developed for this study features durability and versatility. It comprises two distinct parts —a Static System, Part I, and an Analytical System, Part II.

Part I consists of r-f. bombarder coils and sample, diffusion pump, Toepler pump, McLeod gage, and cold traps. An expansion reservoir is available when the sample proves too large for the McLeod gage measurement. This section is used mainly for pressure and volume measurements but low-temperature distillation can be made using liquid nitrogen. A diffusion pump in series with a Toepler pump is used for transferring the gases into the bulb of a McLeod gage. This principle permits handling extremely small samples.

Part II analyzes a fraction of the sample from Part I. The most convenient sample for quantitative analysis is found to be 0.05 to 0.1 cc. The analytical section consists of a diffusion pump for circulating the gases over the chemical reagents, and a Toepler pump which forces the sample into a small McLeod gage (see Fig. 2). The chemical reagents are arranged in a ladder type formation so that a particular chemical absorbent is readily available for specific gas removal. Ascarite is used for CO_2 absorption. Copper oxide and copper furnaces are available for H_2 and O_2 determinations and a lithium furnace for N_2 analyses. The apparatus has been constructed for the analysis of gas samples ranging from 2.0 cc. down to 0.01 cc. Volume measurements are consistently checked in the order of 0.0001 cc. Analyses may be made with errors for each component within 1 percent of the total sample.

APPARATUS

The schematic diagram, Fig. 1, indicates position of various pumps, etc. The Pyrex glass apparatus is mounted on a steel frame 71 in. high, 52 in. wide and 36 in. deep. The Toepler pumps and MacLeod gages are operated by a pressure-vacuum manifold connected to the mercury reservoirs. The manifold pressure is maintained at 8 psig and controlled by the needle valve on a nitrogen cylinder. Two single-stage mercury diffusion pumps, assisted by Toepler pumps, transfer the gas about the system. They may be operated with a third mercury pump and a mechanical pump (Kinney CVD5556) when rapid evacuation of the system is desired.

The capillary tubing in the McLeod gages may be by-passed when moving the sample or evacuating the system (see Fig. 2). This arrangement greatly increases the speed of analysis as evacuation through a capillary is very slow and inefficient. In normal use of the Toepler pump - McLeod gage arrangement, the sample enters at A and is forced into the Toepler bulb B by a mercury diffusion pump. The mercury level is at C in order to capture the sample. About 15 cycles of the Toepler pump are necessary to compress the sample into a small McLeod gage D. The sample is then measured in the gage at a constant volume and the change in pressure is recorded in the long matched capillary. The McLeod gages are constructed with precision-bore capillary tubing. If the sample is to be circulated or the system evacuated, the mercury levels are lowered to the reservoirs G and H and the gases from A and C travel directly out through the absorption train at F. Reservoir G has a safety advantage over reservoir H. The long column prevents a pressure blow-out if any sudden changes of vacuum or pressure occur. The momentum of mercury in motion deserves this precaution.

The absorption train contains a standard group of dry chemical reagents. Ascarite, copper oxide furnace, copper furnace, platinum coil and lithium furnace. Each furnace is operated with Variac control for temperature settings. The copper oxide and copper furnaces are maintained at 350 C. The ladder type arrangement of reagents illustrated in Fig. 1 gives versatility in choice of absorbents for a complex sample.

General Procedure of Analysis

Before any analysis, the system and the reagents are thoroughly outgassed and tested to hold below 1 micron without pumping for more than five minutes.

The sample is liberated by induction heating if metallic, or by a magnetic hammer if contained in glass bulbs. The gas is passed through a series of three

dry ice-acetone cold traps to remove any water vapor before being collected in the McLeod gage and measured as total pressure. The system has been calibrated to convert pressure into volume at standard conditions. A calibrated expansion reservoir is used if any sample proves large for the McLeod measurements.

A fraction of the gas sample, 0.05 to 0.1 cc., is then transferred to the analytical system and collected in the small McLeod gage. The total analytical sample is recorded as pressure at a constant volume. The gas is circulated over Ascarite and through a dry ice-acetone cold trap for several minutes. The Toepler pump is then used to return the sample to the small McLeod gage. The change in pressure at constant volume is proportional to the carbon dioxide removed during the cycling and is calculated in percent CO_2.

The sample is then passed over copper oxide and through cold trap for the hydrogen determination and again over Ascarite for the CO determination as carbon dioxide. The presure is measured after each step. Nitrogen is usually determined as residual gas but a lithium furnace has been installed for argon-nitrogen mixtures.

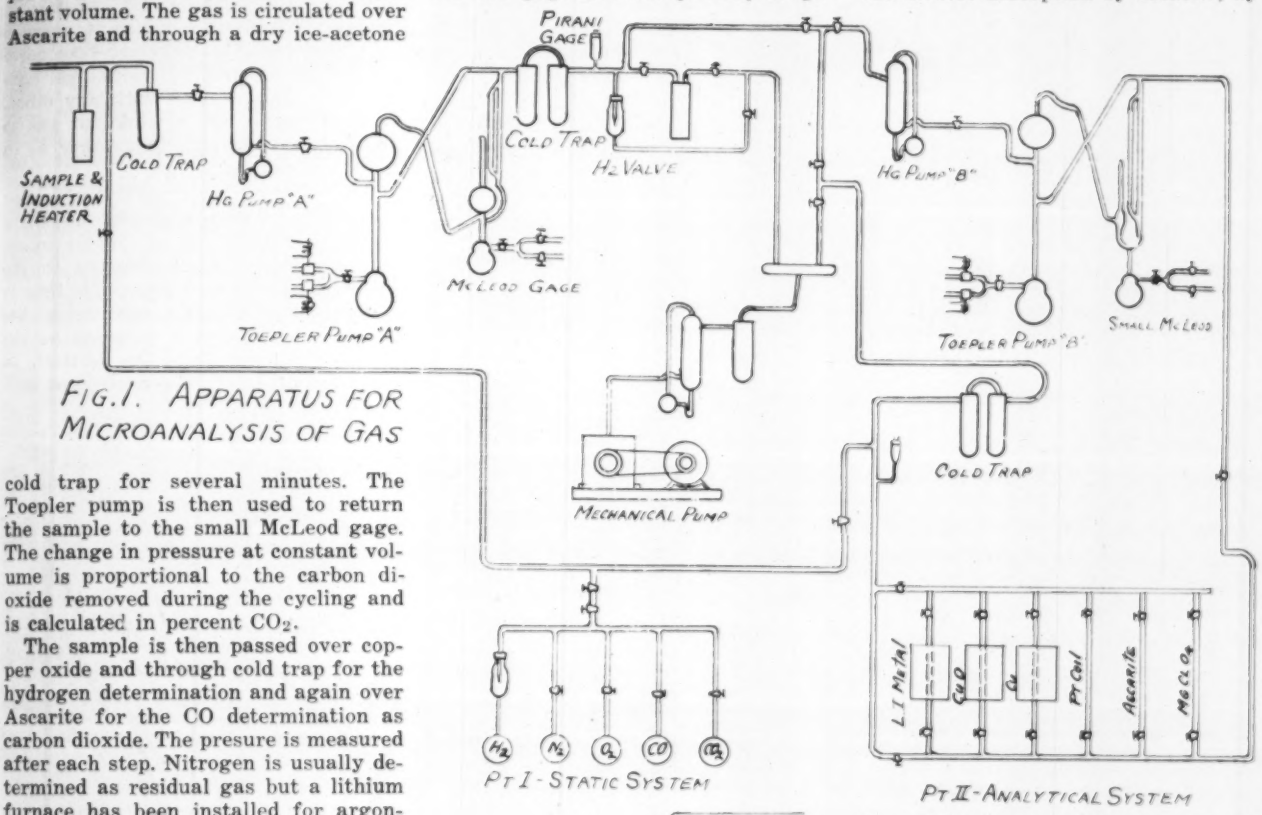


FIG. 1. APPARATUS FOR MICROANALYSIS OF GAS

PREPARATION OF SAMPLES

The sample metals were made into radio anodes by regular production methods. The anodes are hollow cylinders 20 mm. diameter by 24 mm. high and weigh approximately 1.5 grams. All samples were mounted in a regular lock-in type radio tube. The exhaust tube of each sample was sealed directly on the microgas analysis unit.

Two identical sets of materials have been degassed and analyzed. They represent materials as received and materials which have been heated in a reducing atmosphere for the normal clean-up process.

EXPERIMENTAL

An all-glass seal was made to the microgas equipment and the glass envelope containing the sample was baked for 15 minutes at 350 C. A continuous vacuum maintained with mercury diffusion and mechanical pumps removed any gases or water vapor given off by the glass.

Part A — After baking, the oven was removed and the sample heated by induction for 2 minutes at 970 C. A high-frequency water-cooled coil with a 10-kw. r-f. "bombarder" was used in heating the samples. Temperatures of metals during bombardment were measured with a Leeds & Northrup disappearing-filament type optical pyrometer. The gas was collected continuously, as evolved, by a mercury diffusion pump in series with a Toepler pump. The pressure was measured with a McLeod gage and the quantity of gas calculated from the known volume of the system.

In all measurements the gas has been continuously pumped away from the chamber containing the metal sample in order to avoid any recombination of the gases and the metal.

After measurement of the total gas volume, an appropriate fraction (0.05 to 0.1 cc., was transferred to the Analytical System. The sample was then analyzed for percent of each component by the regular procedures, that is, carbon dioxide absorption by ascarite, hydrogen by copper oxide furnace and cold traps, carbon monoxide by copper oxide in series with ascarite, oxygen by copper furnace and nitrogen by difference.

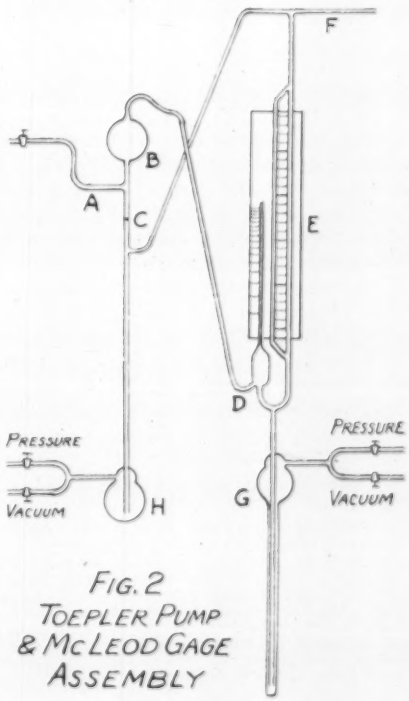


FIG. 2 TOEPLER PUMP & McLEOD GAGE ASSEMBLY

Part B—The gas generated in Part A was removed and the system pumped below 0.5 micron. The metal was again bombarded at a red heat (650 C.) for 30 minutes. The rate of gas evolution was recorded by periodic readings on a Tru-Vac gage. The total gas evolved during the 30-minute period was then calculated from the McLeod gage measurement. Part B was intended to represent an accelerated life test with the metal anode in operation.

Part C — The system was again pumped below 0.5 micron and the metal sample bombarded for 2 minutes at 970 C. as in Part A. The gas evolved was determined with the McLeod gage.

The data for all samples are summarized in Tables I, II and III.*

*Omitted by reason of length and because outstanding data are stated in text; available in photostat form from the authors, 60 Boston St., Salem, Mass.

Continued on Page 360

A New Electric Level *or* Inclinometer *with* Unique Directional Characteristics

By CLARKE C. MINTER, Naval Research Laboratory, Washington, D. C.

A DEVICE for indicating electrically small displacements from the vertical was described in *Instruments*, May 1947, page 394.* The device, called "Position Convectron," depends for its operation on differences in the heating effect of convection currents on two similar temperature-sensitive elements in opposite arms of a Wheatstone bridge. A heater coil in the vertical portion of a Y-shaped tube filled with argon produces convection currents which flow up the two branches of the Y. At the tip of each branch of the Y is a temperature-sensitive resistor connected with other resistors to form a Wheatstone bridge. When the Y is vertical the convection currents heat the two sensitive elements to the same extent and the bridge is balanced. A slight shift from the vertical produces unequal heating of the two sensitive elements and the bridge becomes unbalanced, thereby giving a quantitative indication of the angular displacement from the vertical.

During an investigation of the effect of filament position relative to the vertical on the accuracy of thermal-conductivity gas-analysis apparatus, it was observed that in certain designs gas convection currents over the filaments became relatively quite appreciable. Instead of trying to suppress the convection currents entirely, a way was found to control them so that the effects due to convection could either be eliminated entirely or employed to indicate slight displacements of the filaments around a given axis. It is felt that this incidental development (though it was not planned as part of the research program) is of sufficient value to be announced.

The "Electric Level" described below operates on the same general principle as the "Convectron" referred to above; namely, by differences in the relative heating effects of gaseous convection currents on temperature-responsive elements in a Wheatstone bridge. There are differences in design, however, which appear to give the Electric Level certain advantages.

The Electric Level is shown schematically in Fig. 1.

The current-heated temperature-responsive elements are carefully matched and positioned at right angles to one another in two similar sealed cells, about 0.75 inch in diameter, cut into a metal block. The cells are filled with a heavy gas such as argon. Two matched manganin coils complete the bridge. A constant current is supplied by a battery and a ballast lamp and an indicator calibrated in degrees* shows to what extent the metal block is displaced from the vertical around the axis A. Any rotation around the axis B-B has absolutely no effect on bridge balance, and the indication gives only the rotation around the axis A. The bridge is balanced when the sensitive elements make an angle of 45 degrees with the vertical, and the maximum indication in either direction is obtained when one element is vertical and the other horizontal.

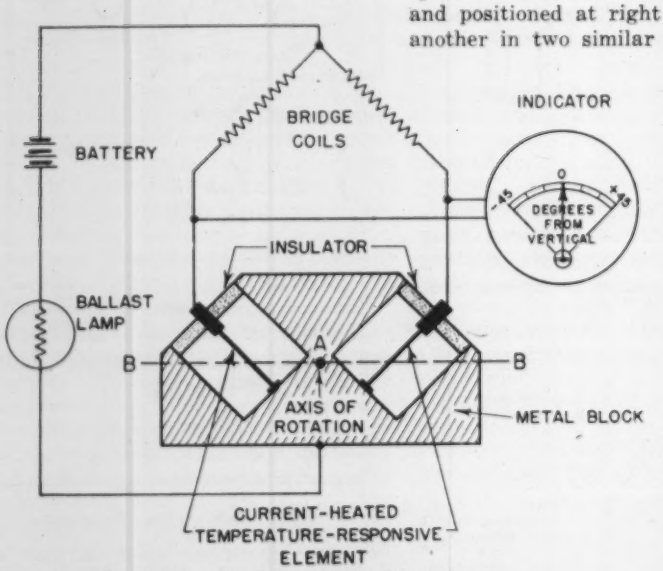


Fig. 1. Schematic diagram of the Electric Level.

In the Electric Level there is no external heater-coil for the production of convection currents but each temperature-sensitive element acts as its own heater. This design makes it possible to place each temperature-responsive element in a sealed individual cell having no communication with any other. It therefore is not possible for gas to "slip" from one arm to another as in the "Convectron."

By combining the functions of heater and temperature-responsive element in the same resistor, it is possible to obtain extremely rapid response to the slightest change in position. No time is lost in readjusting the equilibrium between two convection currents as the position changes from the vertical. In the Electric Level the convection currents in equilibrium with a current-heated temperature-sensitive element depend on the angle the element makes with the vertical and, as soon as the angle is varied to the slightest extent, there is an immediate change in the convection currents on the heated element itself, and an almost instantaneous change in bridge balance is obtained. Equilibrium is reached much more quickly with the Electric Level than would be the case with the "Convectron."

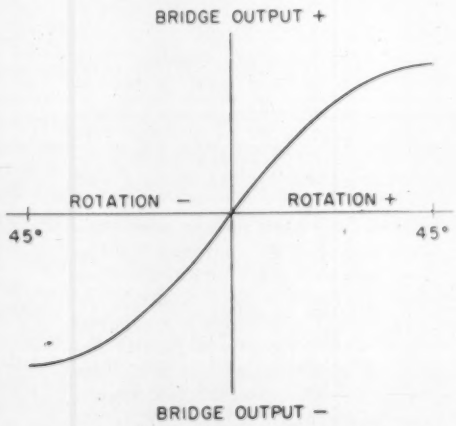


Fig. 2. Type of output curve obtained.

Fig. 2 shows how the output from the bridge varies with rotation about the sensitive axis. As can be seen, the Electric Level is most sensitive to change when the bridge is perfectly balanced; that is, when both filaments are 45 degrees to the vertical, as in Fig. 1.

The Electric Level has certain advantages over the gyroscope and should find several applications in aircraft and rockets—not only as an indicator but also in automatic-control apparatus.

*Made by Eclipse-Pioneer Division, Bendix Aviation Corp., Teterboro, N. J.

*EDITOR'S NOTE.—In Fig. 1 the author shows a quadrant scale, presumably for applications requiring a "true picture" of angularity, as in some gyroscopic flight-attitude instruments (artificial horizon, etc.), but for applications requiring greater sensitivity a calibration in minutes could be obtained by selecting a zero-center electrical instrument of the desired full-scale sensitivity.—MFB.

A New Magnetic Method *for* Measuring *the* Thickness *of* Composite Copper-nickel Coatings

By ABNER BRENNER and EUGENIA KELLOGG, National Bureau of Standards, Washington, D. C.

A CONVENIENT non-destructive magnetic method for determining the thickness of composite copper-nickel coatings electro-deposited on steel has been developed at the National Bureau of Standards.

The method involves the measurement of the attractive force between the plated specimen and two permanent magnets of different strengths. The values thus obtained are used, in conjunction with a set of previously-determined calibration curves for each magnet, to obtain the total thickness of the coating and the relative thicknesses of the copper and nickel layers.

Composite coatings, in which nickel is deposited over a layer of copper, are used extensively in the automotive and other industries for the economical protection of steel against corrosion. Since their protective value depends largely on their thickness, it is important to have a convenient means for measuring thickness.

In the usual procedure, the plated article must be destroyed to provide a cross section for microscopic examination. The new magnetic method is non-destructive and is easily and rapidly applied. It utilizes the principle of the Magne-gage, an instrument originally designed at the Bureau to measure the thickness of single electrodeposited coatings on the basis of the attraction between a small permanent magnet and the plated sample. The Magne-gage is essentially a spring balance, on the arm of which a magnet is suspended in contact with the coated surface. A helical spring is so attached that, when wound by means of a knob, it exerts a force tending to detach the magnet from the surface. If, as is ordinarily the case, the coating is less magnetic than the object plated, the required force, as indicated on a dial adjacent to the knob, will be greater for thinner coatings.

For measurement of composite coatings, the Magne-gage is modified by the use of two magnets of different strengths. Calibration curves for each magnet — total thickness versus dial readings—are plotted on transparent material for coatings of successively varying known proportions of copper and nickel. After readings are taken with each magnet on the composite coating under study, one set of calibration curves is superposed on the other in such a way that the values of the two separate dial readings on the horizontal scale for each magnet are brought into coincidence. A straight line is drawn joining points of intersection of curves of the same percentage composition. If a second line is then drawn, perpendicular to the horizontal scales of the graphs, through the point representing the dial readings, it will intersect the first line in a point corresponding to the thickness of the total coating. The relative thicknesses of the copper and nickel layers are also obtained by graphical interpolation along the line joining the intersection points of the curves of equal composition.

In this way, total thicknesses of composite coatings ranging from 0.0005″ to 0.003″ can be determined within about 10%. The thickness of each component layer of similar coatings can be measured to an accuracy of about 15%.

Thickness of composite copper-nickel coatings electrodeposited on steel is now determined at the NBS through use of the Magne-gage, an instrument previously developed at the Bureau, which indicates the force exerted by a coiled spring in detaching a small permanent magnet from the plated sample. For measurement of composite coatings the instrument is modified to include two magnets of different strengths.

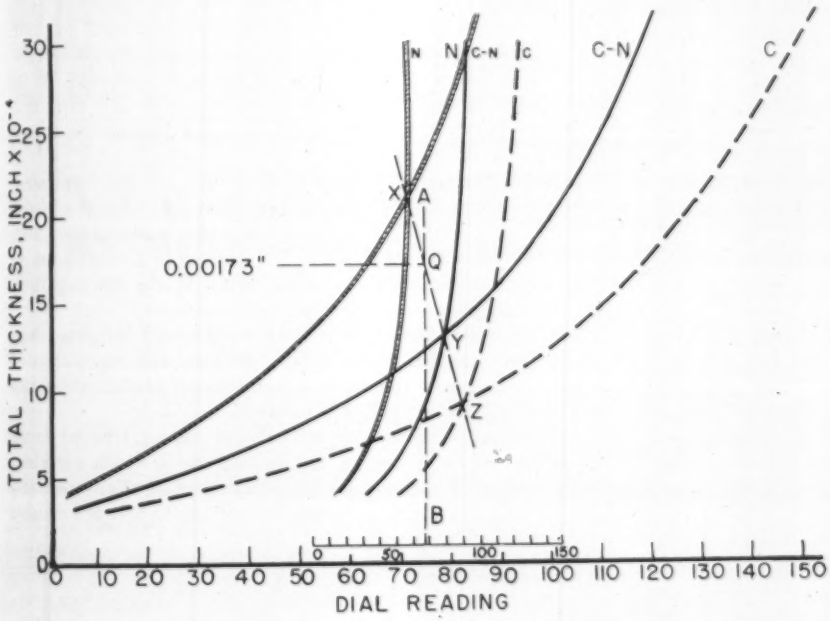


Diagram illustrating graphical method developed at the NBS for use with the Magne-gage in determining thickness of composite copper-nickel coatings. Two previously-prepared sets of calibration curves—one set for each of two magnets of different strengths in the Magne-gage —are used. After readings have been taken with each magnet on the composite coating under study, one set of calibration curves is superposed on the other, as in the figure. This is done by sliding the horizontal scales of the two graphs along each other until the two separate dial readings for each magnet are brought into coincidence at B. In each case the curves labeled N, C-N, and C are for compositions of 100% nickel, 50% copper, and 100% copper, respectively. However, those for the weaker magnet have much greater slopes. A straight line (XYZ) is drawn joining points of intersection of curves of the same percentage composition for the two different magnets. If a second line AB is now drawn through B perpendicular to the horizontal scales, it will intersect the line XZ in a point Q. The ordinate of Q, read from the vertical scale common to both graphs, is then the thickness of the total coating (here 0.00173″). The relative thicknesses of the copper and nickel layers are also obtained by graphical interpolation along the line joining the intersection points of curves of equal composition. In this case, for example, since Q lies along XZ about 40% of the distance from the half-copper curve to the nickel curve, the copper content of the coating is (40/100) × 50 =20%.

"HEAT INERTIA" *in* Problems *of* AUTOMATIC CONTROL *of* TEMPERATURE

By VICTOR BROIDA, Consulting Engineer, Paris, France.

PART III

ACTUAL CONTROLLERS

We have up to now studied theoretically the influence of what we termed the "fictitious mass" of a heating unit on the different factors involved, in the case of heating units not provided with automatic temperature controllers as well as in the case of heating units subjected to discontinuous or continuous automatic control. We have reviewed the various automatic temperature control systems and we drew conclusions regarding the part borne by the fictitious mass of the heating unit in every particular case of each of these systems.

We shall now complete this essay by a series of examples of practical realizations embodying the conceptions which up to now we have studied theoretically. We shall therefore describe a series of automatic temperature controllers corresponding each to one of the automatic-control systems which we have already studied theoretically; and we shall outline in every particular case the similitude which exists between the theoretical conclusions drawn from the mathematical study of these systems and the practical conclusions which we shall have to make from the investigation of the corresponding instruments.

We shall not consider the principle of temperature measurements involved in the described automatic controllers, i.e., we shall not consider whether the case under review is that of vapor-tension, gas-filled or mercury thermometers, etc., as this is of no importance from the standpoint of the operation of the control system itself.

We shall consider the example of a series of air-operated temperature controllers manufactured by an American firm, these instruments being a large series of more and more complete controllers, each automatic-control system being obtained from the preceding one by adding complementary parts. It should be understood that our choice of this American series is determined by the particularly clear way in which the various controllers described illustrate our preceding theoretical demonstrations: there are, of course, other types of pneumatic controllers just as there are various types of hydraulic, electrical, mechanical and electronic systems for the automatic control of temperature. The choice of power for operating the final element has no more importance to us than the choice of the primary element, as our classification is based on the general law which applies to the automatic temperature control systems.

Finally, we shall assume, in all the considered examples, that the automatic temperature controller will command—through an appropriate air-piping—a diaphragm-motor valve which alters in a convenient way the flow of a heating medium circulating in the controlled heating unit. This heating unit will therefore be a heater of any kind. But we could just as well consider, instead of a diaphragm valve, one or several motors commanded by the automatic temperature controller and controlling in turn the input of fuel, the input of combustion air, the opening of draft dampers, etc., and the heating unit would then be a boiler or a furnace for any industrial or domestic purpose.

DISCONTINUOUS-ACTION CONTROLLERS

We shall begin with the study of the simplest controllers: those having a discontinuous action.

These controllers have a total action which consists in opening entirely the controlled valve when the temperature inside the heating unit decreases beneath the lower limit of control θ_2; or in closing this valve either entirely (in the case of On-off Control) or to a certain extent (in the case of High-low Control) when this temperature rises beyond the higher limit of control θ_1. The difference between On-off Control and High-low Control consists merely in the existence of a given flow of heating medium when the controlled valve is closed under the latter, and in the non-existence of this minimum heat input to the heating unit under the former; the same temperature controller can therefore be used for On-off Control as well as for High-low Control and it is sufficient in this latter case to provide the valve commanded by this controller with an adjustable by-pass.

Therefore, the main feature characterizing this system is the immediate and sudden movement of the controlled valve or motor from one extreme position to the other for a given variation of the temperature in the heating unit, this variation being equal to the neutral zone or "dead zone" or "differential" existing between the two limit temperatures of control.

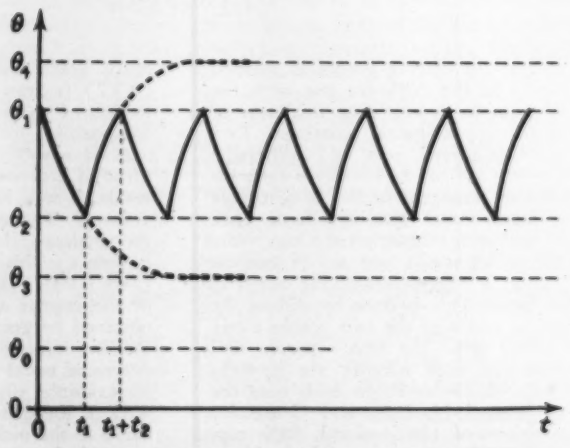
Before describing this type of controller, it will be necessary to make a remark of the utmost importance.

We assumed, when we traced, in solid line in Fig. 3, the diagram of temperature variations inside the heating unit (the case of discontinuous automatic control) that the minimum heat input to the heating unit was automatically replaced by the maximum input as soon as the decreasing temperature inside this heating unit reached the lower limit of control θ_2; this resulted in a new increase of this temperature above θ_2 and, in this way, the temperature in the heating unit never decreased beneath the lower limit of control θ_2.

In a similar way, we assumed that, as soon as the increasing temperature in the heating unit reached the higher limit of control θ_1, the maximum heat input to this heating unit was automatically replaced by the minimum input, which resulted in a new decrease of this temperature; thus, the temperature in the heating unit never increased above the higher limit of control θ_1.

These theoretical assumptions were based on an instantaneous or nearly instantaneous action of both the automatic temperature controller itself and of the valve or motor under control when the corresponding limit of control is reached.

This is true of the controller itself and almost true of some quick-acting valves or motors, for instance those which are electrically-operated; it can be quite different in the case of air-operated or of hydraulically-operated valves or motors. This is the reason



(Fig. 3, reprinted from February issue for readers' convenience)

for our choice of one of these examples; and the assumption on which the diagram in Fig. 3 is based is no more true.

Indeed, in the case of these air-operated or hydraulically-operated control systems, any change in the position of the controlled valve requires a flow—in one direction or in another—of the medium whose pressure acts on its diaphragm; this flow is not instantaneous and the operation of the controlled valve is different in this case from that of quick-acting electrically-operated or mechanically-operated valves.

We can therefore say that the true graph of temperatures inside a heating unit provided with an air-operated or hydraulically-operated discontinuous automatic-control system never corresponds exactly to the theoretical solid-line tracing in Fig. 3 and that these temperatures extend beyond the limits of control θ_1 and θ_2 at which the controller action is started in one direction or in another. However, if the time required by the controlled valve to open or to close is very short, the extent to which the limits θ_1 and θ_2 are over-run is also very small and we may accept the theoretical tracing in Fig. 3 as a sufficiently accurate diagram.

We shall see now what would happen in reality if the time required by the controlled valve to open or to close could not be neglected; for instance, when the decreasing temperature inside the heating unit would reach the lower limit of control θ_2, the controller would start to open the controlled valve, which would thus move—at a given speed—from its minimum position to its maximum position instead of doing so instantaneously.

The position of the controlled valve would, therefore, become at this moment, a direct function of the time elapsed from the start of the controller action and the whole system would thus no more operate under discontinuous control—the characteristic feature of which is the sudden movement of the controlled valve from one of its extreme positions to the other—but under floating control, the characteristic feature of which is the continuous variation of the heat input to the heating unit in function of the time elapsed alone. The temperature inside the heating unit would therefore decrease below the lower limit of control θ_2 (see Fig. 6), would be balanced

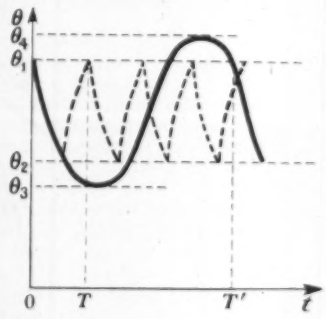


Fig. 6

at a temperature $\theta_3 < \theta_2$ and would then increase up to θ_2 and further on until the moment when a new start of the controller action at the higher limit temperature θ_1 would again close the controlled valve.

This closing of the controlled valve would require, just as its opening, some time during which the whole system would again operate under floating control instead of discontinuous control; the temperature inside the heating unit would thus over-run the higher limit of control θ_1, would be stabilized at a temperature $\theta_4 > \theta_1$, would again decrease down to θ_1, and so on.

This temperature would therefore cycle between real limits θ_4 and θ_3 wider than the limits of control θ_1 and θ_2; and the system comprising the automatic temperature controller and the valve commanded by the latter would operate under discontinuous control for temperatures inside the heating unit within the limits of control θ_1 and θ_2 and under floating continuous control for temperatures between θ_2 and θ_3 on one hand, θ_1 and θ_4 on the other hand.

We can see (solid line in Fig. 6) that the period T' of a complete cycle of temperature variations inside the heating unit with this delayed operation of the controlled valve, is greater than the period T of the same cycle with an immediate opening of this valve, i.e., the dotted-line theoretical tracing of the curve $\theta(t)$.

We have already seen when we studied the features of continuous automatic control (and, in particular, those of floating or positioning plus floating continuous control) that temperature intervals such as θ_2-θ_3 or θ_4-θ_1 in Fig. 6 decrease with the increase of the fictitious mass m and with the increase of the coefficient K_1—which in this case is proportional to the rate of opening or of closing of the controlled valve. These intervals are therefore smaller in heating units having a comparatively high fictitious mass and, on the other hand, they are decreased by the speed of opening or of closing of the controlled valve and cut down to 0 when $K_1 = \infty$, i.e., when this valve opens and closes instantaneously.

Therefore, the slowed-down opening or closing of the controlled valve, although it has a positive influence on the frequency of temperature variations inside the heating unit (decreasing this frequency), has a negative influence on the amplitude of these variations (increasing this amplitude).

We can thus conclude that it is useful—if we want to obtain conditions as close as possible to those of a perfect discontinuous control—to minimize the time required for closing or opening the controlled valve. This is even more important when the fictitious mass—which limits the extent of temperature intervals—is low and, generally speaking, the discontinuous automatic control should not be used with heating units having a too low heat inertia.

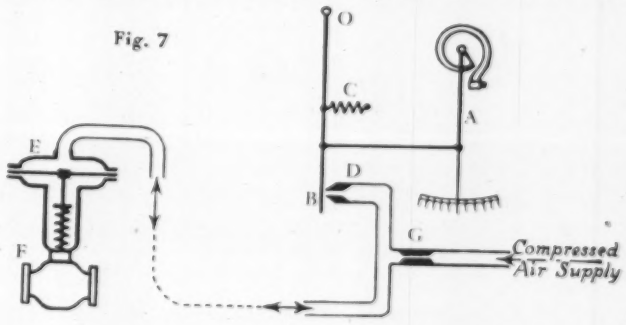
This being stated, let us look into the general principle of an air-operated discontinuous automatic temperature controller.*

SIMPLE "ON-OFF" TYPE

The "On-off" or "High-low" Control device in its simplest form would comprise (see Fig. 7) a pen or an index A (of the thermometer) actuating a flapper B pressed by a spring C against an air-nozzle D connected to the same supply of compressed air as the diaphragm E of the controlled valve F.

A reducer G would be inserted in the air piping feeding nozzle D and diaphragm E so that a slight flow of air through this nozzle, resulting from a slight movement of flapper B to the left, would

Fig. 7



suffice to create considerable pressure drop through this reducer and therefore—the pressure of supplied air, before this reducer, remaining constant—a considerable decrease of the pressure existing after this reducer so as to cut down to zero all pressure in this part of the device for a slight movement of pen or index A.

Under these conditions, when the temperature inside the heating unit decreases below the lower limit of control, pen A moves to the left, uncovering slightly nozzle D and creating a slight flow of air. This lowers the pressure after reducer G down to atmospheric pressure—which, in turn, results in a flow of air (which exerts its pressure on diaphragm E of controlled valve F) outside of the controller, this air being exhausted from the pipe which connects diaphragm E to the controller and flowing out through nozzle D.

The pressure on diaphragm E is therefore also lowered down to atmospheric pressure and controlled valve F will, under the action of its spring, open to its maximum extent in order to insure the full flow of heating medium instead of the minimum heat input (or none) to the heating unit.

Continued on Page 362

* The four schematic diagrams, Figs. 7, 8, 9 and 10, pertain to the instruments made by the Brown Instrument Company of Philadelphia, U.S.A., but the discussions of principles apply equally well to the products of numerous American and European instrument companies.

The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

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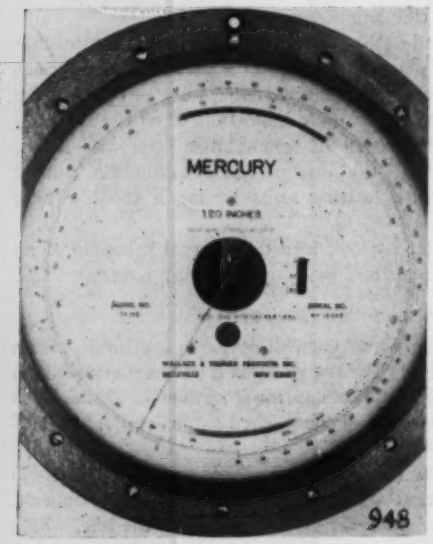
High-precision Dial Manometer

New "Type FA-145" precision dial manometer is available in two standard ranges: 0 to 120 in. water and 0 to 120



in. mercury (special ranges up to 200 in. mercury custom-built). Scale is furnished in any desired pressure equivalent. Dial diameter is 8.5 in. but scale is actually 45 inches long in two revolutions of pointer. Every instrument is calibrated against a liquid-column Standard at 100 points (or more) and scale is hand-drawn, usually with about 1000 graduations. Zero may be suppressed up to max. of 25 percent of range (depending on range). Antiparallax mirror minimizes reading errors. Ultimate sensitivity is 0.01 percent of scale range; accuracy 0.1 percent; temperature correction 0.0375 percent per deg. C.; standard calibration temperature 22 deg. C.; hysteresis (max. effect) 0.2 percent for full-range change in pressure.—*Wallace & Tiernan Products, Inc., Belleville 9, N. J.*

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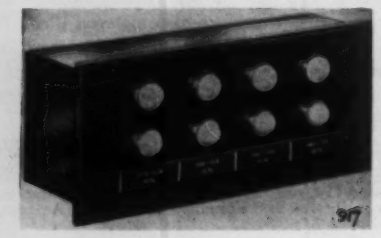
Multiple-signal Systems

New "Series 300 Panalarms" are said to represent a new conception in industrial signal systems for process work, power plants and other applications where both audible and visual alarms are required to indicate failure or off-normal changes. Alarms are designed to make possible safety shut-downs, sequencing or inter-locking of plant operations. They may be actuated by any remote switch, thermostat, float-switch, etc. Safety and reliability are insured by making lamps glow dimly during normal operation. If signals go out of service or bulbs burn out, operator knows this at once. Where there is an abnormal condition, two signal lights go on and a warning is given by a horn or other sound device. Horn is turned off and white lights goes off but red lights stays on, when failure is acknowleged by operator. Horn is immediately back in service for monitoring any further failure. Thus, a single horn serves for any number of alarms. Many combinations of lights and signals are available to indicate trouble line, also to indicate when corrective measures have been taken, and finally when line is cleared back to normal. Up to 12 units may be had in a single cabinet. Each cabinet contains a wiring strip capable of receiving any combination of various alarm units. Any unit may be removed and replaced in seconds without disturbing the others. Flexibility is insured by allowing extra spaces in cabinet for spare units. In early stages of design, user selects a large enough cabinet; actual units can be selected and plugged in later. Cabinets are adapted to flush mounting on central control panels or to wall mounting. Systems come completely wired.—*Panalarm Products, Inc., 7216 N. Clark St., Chicago 26, Illinois.*



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Portable Vibration Detector

New portable "Sono-Probe" is smaller version of maker's industrial model noise and vibration measuring system.

Weighing 10 lbs., instrument can be employed as leak detector, for trouble shooting and maintenance applications. Operates from batteries, has scale graduated from 0 to 100. Earphones also are provided for periodic checking of machines to discover wear. Amplification is variable up to 700 db. and range is 100 to 20,000 cps.—*Aircraft Electronics Associates, 1031 New Britain Ave., Hartford 10, Conn.*

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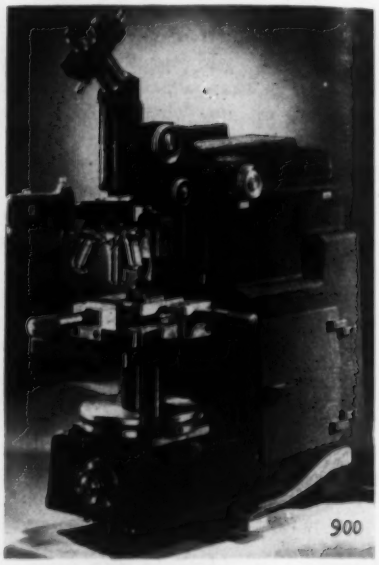
New micro hardness tester is said to be first to apply accurately dead-weight loads as light as 1 gram, for use with



either Knoop indenter or Vickers-type indenter. Accurate application of 1-gram dead-weight load is said to open new avenues in testing minute particles, inclusions, constituents, thin metals, transition zones of welds, wire, foil, ceramics, glass, enamels, plastics and jewels, both natural and synthetic. Tester has adjustable oil dash pot for controlling speed of load application and time of load retention. Mechanical stage — consisting of stationary plate, transfer plate and specimen block — provides convenient means for positively locating and positioning exact area of test specimen. Dead weights for applying loads of 1 to 1000 grams, and optical measuring equipment, are supplied as standard equipment — *Kent Cliff Labs., Peekskill, N. Y.*

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CRO-display Marker

New "Megaligner" marking device covers frequency range from 19 to 49 Mc. including all present and proposed i.f. bands. It has a self-contained power supply and provides a tunable C.W. signal which may be used as a signal

source or with maker's "Mega-Sweep" to produce a tunable "birdie" type marker on an oscilloscope display. In addition, when used with "Mega-Sweep," a tunable "pip" type marker is available which is connected directly to vertical amplifier of display oscilloscope. "Pip" marker does not overload receiver nor disappear in traps. Two markers have independent amplitude controls and accuracy of instrument is 0.5 percent of full scale.—*Kay Electric Co., Pine Brook, N. J.*

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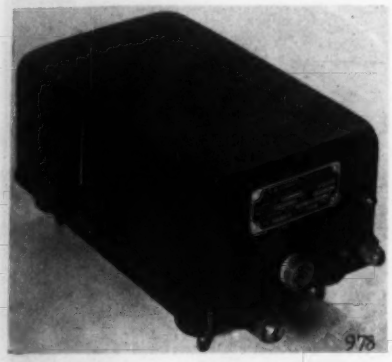
New automatic fuel metering unit, for use with turbojet, ram-jet and pulse-jet engines, provides constant fuel flow



to engine for any fixed condition of airspeed, altitude, and air temperature, regardless of changing metering pin surfaces, pump output variations, or flight load changes and vibrations. Manual controls are provided for rapid easy-to-make adjustments to peak efficiency in varied installations.—*G. M. Giannini & Co., Inc. 254 West Colorado St., Pasadena 1, Calif.*

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Rate and Position Telemetering Gyros

New telemetering rate gyros for rotational measurements from 10 to 1000 deg. per sec.; and position gyros with

one- and two-axis electrical primary elements; are announced. "No. 2311" (illustrated) has range of plus-or-minus 300 deg. per sec.; undamped natural frequency 21 cps.; 2500-ohm pickoff; no damping; resolution under 15-G load 1.6 deg. per second; linearity error 2 percent of full scale; size 2.62x3x4.25

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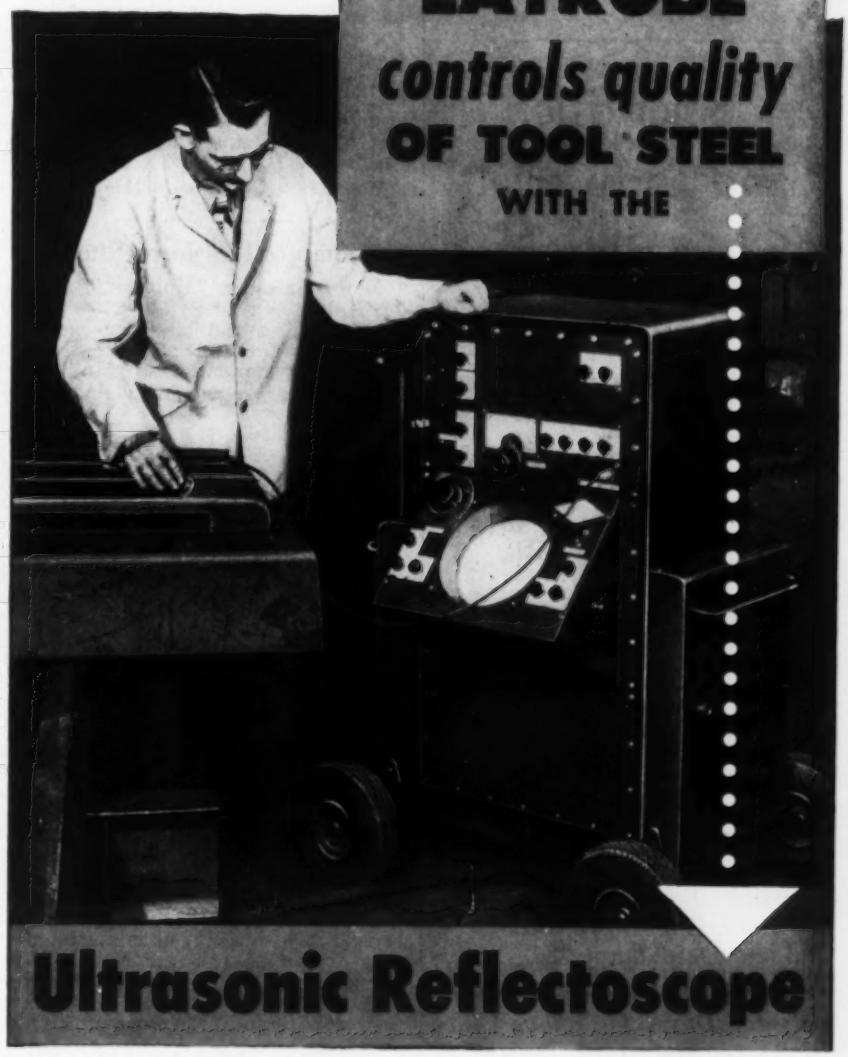

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Miniature Multiturn Rheostat

New miniature "Multipot," said to be smallest ten-turn rheostat ever produced (length and diameter each one inch), embodies the same construction features as standard-size "Multipots," is for use where extremely fine resist-

ance adjustments are required in limited space. "Paliney" contacts plus maker's coil-forming technique are said to result in maximum degree of mechanical smoothness and electrical quietness: each unit is individually checked in an ultra-high gain circuit, "passed only if it is entirely free from contact noise," and backed with an unqualified guarantee. Linearity of miniature unit can be held to within plus or minus 0.1 percent and of next larger model (1 in. diameter and 2 in. length) to within plus or minus 0.05 percent. Almost any resistance up to 20,000 ohms can be produced in the smallest model. Power rating, 1.5 watts.—*Ford Engineering Co., Box 153, Los Angeles 41, Calif.*

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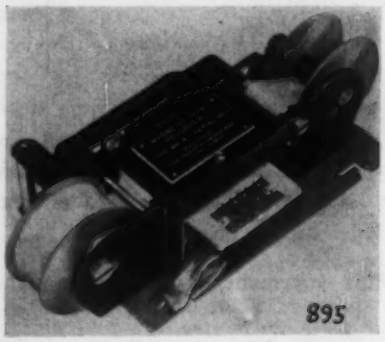
Magnetic-tape Recorder

New "Type MR-4" is addition to maker's line of data recorder mechanisms for use with suitable coupling

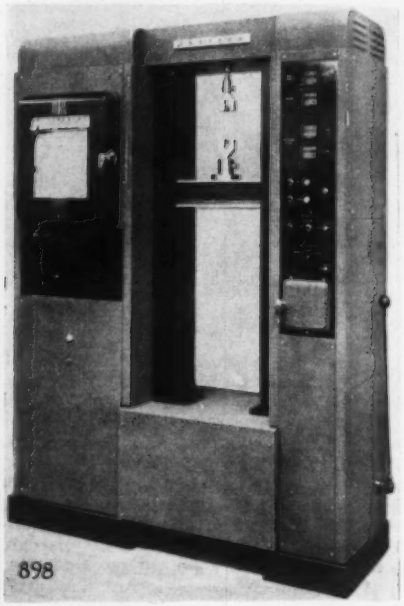


equipment and sensing instruments as a complete recording system. It withstands high shock accelerations up to 75 G's. "Type MR-4" recording mechanism is 13-channel unit weighing but 24 oz. It includes one reference frequency oscillator plus 12 information channels and has a recording time of 2.5 minutes. Unit uses magnetic tape to store variable or transient data under conditions of severe shock acceleration for later re-running and analysis.—*Cook Research Labs., 1457 Dempsey Prky., Chicago 14, Ill.*

Mention No. 409 when filling out card

Autographic Tensile Testing Equipment

New tensile tester makes possible accurate load-elongation measurements of plastic and textile materials, wire, paper, rubber, adhesives and similar specimens. Full-scale load range extends from 2 grams to 5,000 lbs., choice

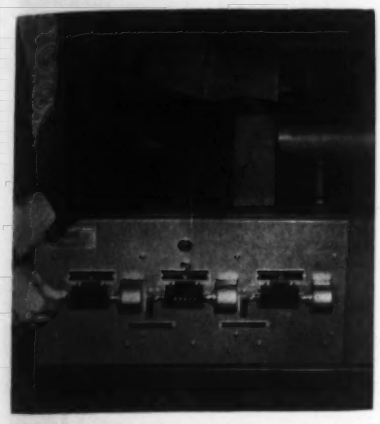


of jaw speeds ranges from 0.02 to 20 in. per minute. Tester permits variety of unique testing techniques for determining special properties. Instrument utilizes electrical weighing system based on electric strain gage principle for detecting and recording load applied to sample. Pulling jaw drive provides controlled rate of elongation of sample, over wide range of speeds, in either direction of travel, and with instant reversibility. Chart of high speed recorder is driven at various speed ratios with respect to this jaw, so that tensile load-elongation curves of material are made accurately at constant rate of elongation. Power to actuate moving crosshead is derived from servo-controlled drive, and low power reference unit is driven synchronously at various speeds through set of light change gears. Almost no lag or error is introduced at reversal, enabling measurements of hysteresis under cyclic conditions with accurate correspondence between head position and chart travel. Operation of pulling head is controlled by pushbuttons. Chart speeds range from 0.2 to 50 in. per minute, providing magnification ratios up to 1000 to 1.—*Instron Engineering Corp., 2 Hancock St., Quincy 71, Mass.*

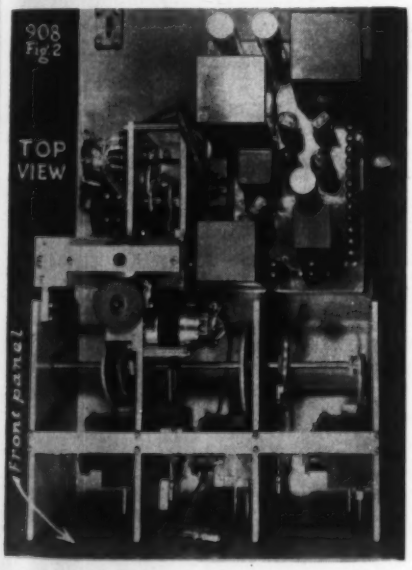
Mention No. 410 when filling out card

Color Computing Instrument

New "General Aniline-Librascope Tristimulus Integrator," is described as "an automatic instrument so precise it can distinguish more than 100,000,000 colors . . . figures out the answer to a series of computations involving integral calculus before a man attempting the same job by hand can sharpen his pencil." Instrument was designed for use with the General Electric Spectrophotometer. Only minor modifications of spectrophotometer are required, and computer may be placed inside the existing case as shown in Fig. 1. Data on



light sources and sensitivity of average eye were standardized by the ICI in 1931, and data on reflectance or transmission of a colored sample may be obtained from recording spectrophotometer. These values must then be combined mathematically to give tristimulus values, which are a unique specification of color observed. New computer multiplies data at each wavelength and sums up products to obtain these three numbers automatically. Ball and disk integrators, cams, and counters are used in computer mechanism (see Fig. 2). Data from recording spectrophotometer



are introduced by means of Selsyn transmitters and servo systems while data on the light source and eye sensitivity are cut on cams. Calculations are completed within the 2.5 minutes required for measurement of a sample in spectrophotometer. Computer calculates

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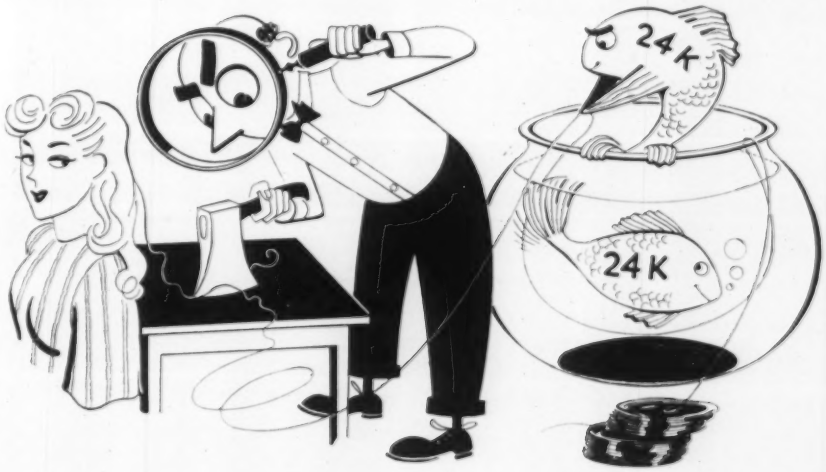

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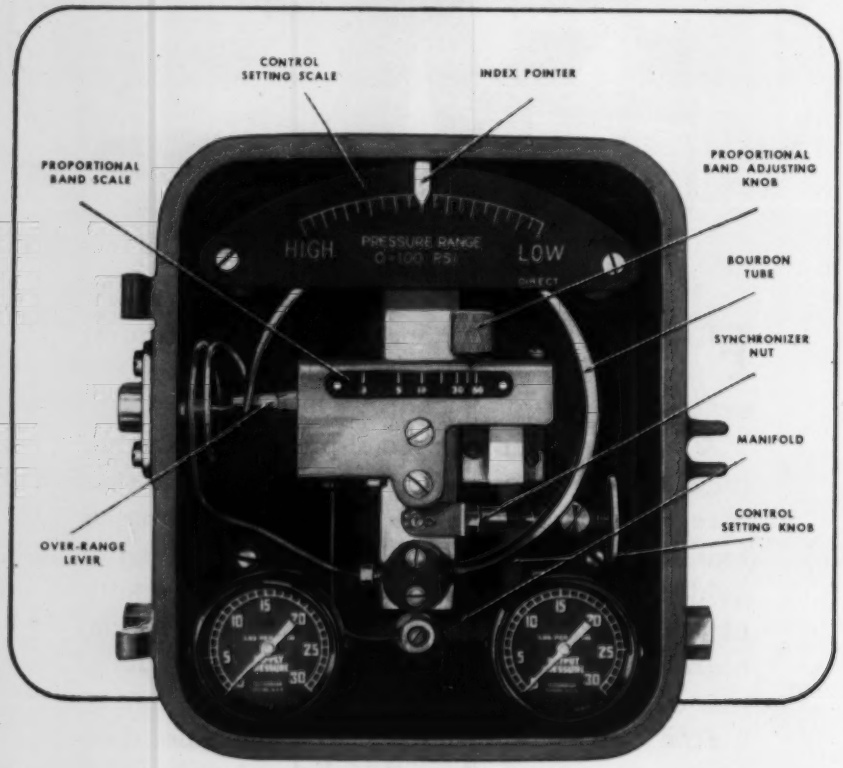
Announcing

No. 2700 Pressure Controllers

Providing Precise Response and Proportional Control at Moderate Cost



These controllers are designed for many industrial applications requiring accurate control where more expensive instruments are not warranted.

Applications include, among many others, pump governors, steam pressure reducing stations, gas well pressure reduction, etc., requiring small to intermediate proportional band.

The case is rugged and suitable for outdoor service; it is so designed that it may be mounted on the valve (on integral pad or by means of a U-clamp) or, *if the occasion arises, it may be removed from the valve and mounted on a wall.* A flush type case is also available for panel mounting.

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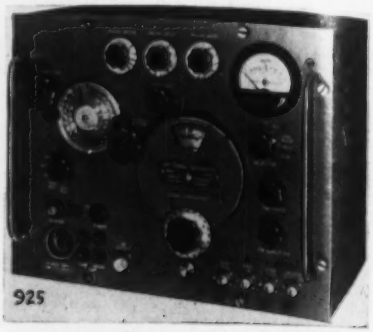
the tristimulus values with a precision of about five-hundredths of one percent. —*General Aniline & Film Corp., 230 Park Ave., New York* 17, N. Y.

Mention No. 411 when filling out card

High-frequency Signal Generator

New "Model 614 A" signal generator for fast readings between 800 and 2,100 Mc. does away with charts and interpolations, since readings are made direct in either microvolts or decibels. Carrier frequency is also set and read directly on large central tuning dial. Instrument has constant internal impedance SWR of 3 db and accuracy is plus or minus 1 db. R-f. output ranges from 0.1 volt to 0.1 microvolt, and may be continuous, pulsed or frequency-modulated at power-supply frequency. Instrument can be modulated externally or internally, and may be synchronized with positive or negative pulses or sine waves.—*Hewlett-Packard Co., 395 Page Mill Road, Palo Alto, Calif.*



Mention No. 412 when filling out card

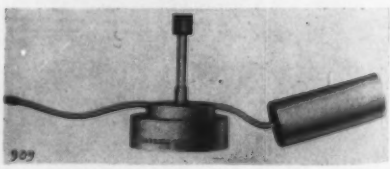
Instrument Heaters

New "Type TMO" line of "Chromalox" multiple-element electric immersion heaters for high-pressure high-temperature applications comprises units from 1 to 100 kw., obtained by arranging groups of tubular elements in extra-heavy mounting flanges. They are recommended for maintaining constant temperatures of instruments installed in locations where temperature extremes, drafts, etc., prevail. They are useful also for preheating air or other gases, superheating steam, etc.—*Edwin L. Wiegand Co., 7592 Thomas Blvd., Pittsburgh, Penna.*

Mention No. 413 when filling out card

TC Assembly for Thermal Radiation Measurements

New Horning-O'Keefe type thermocouple assembly has extremely high sensitivity and fast response. It is particularly suitable for thermal radiation measurements, employing chopped or modulated radiation at frequencies up to 10 cps. Active target surface 0.75 mm. square; spectral range with KBr window 0.3 to 25 microns; resistance between 6 and 10 ohms; d-c. sensitivity greater



than 6 volts per watt is obtained for a time constant of approx. 35 milliseconds. Dimensions of thermocouple case have been chosen to subtend approx. 10 percent of the area of a 60-mm. diameter spherical mirror when housed thermocouple is placed at its focus. Case is provided with an activated charcoal trap which serves to absorb gas which may leak into or be released from interior walls. New unit is available in the following forms:—compensated or uncompensated; mounted or unmounted; evacuated and with charcoal trap.—*Farrand Optical Company, Inc.*, 4401 *Bronx Boulevard, New York* 66, *N. Y.*

Mention No. 414 when filling out card

Magnetic Clutch

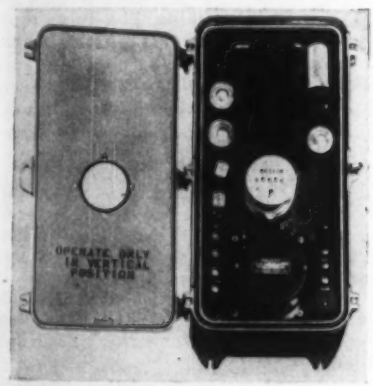
New magnetic clutch for instrumentation is 4.5 in. long, 1.62 in. diam.; transmits torque of 12 in.-lbs. on 110 volts

d.c. under continuous load. Operating current is 0.125 amps. Small power pack available for use on 110 volts a.c.—*Danco Instruments, Co., P. O. Box* 387, *Huntington, N. Y.*

Mention No. 415 when filling out card

Sensitive D-c. Integrator

New "Model 808," integrator, designed for use in general industrial and research applications, provides means for simple and effective integration of d-c. potentials or currents with respect to time. Fundamental elements are mak-

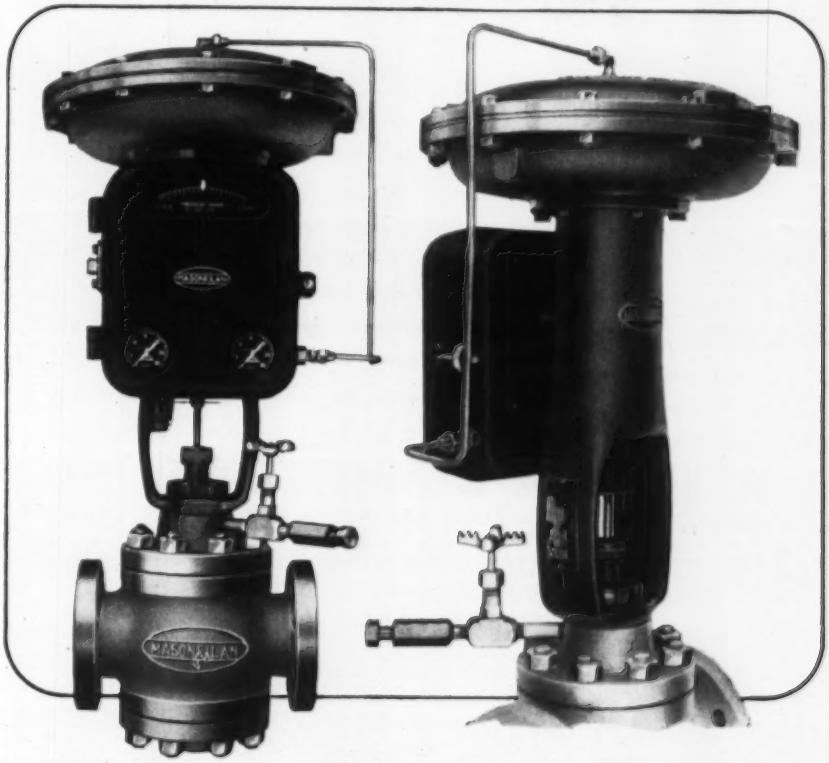


er's "Model 806 Integrating Relay," an electronic relay circuit with associated sealed reed type relays, and a counting mechanism. "Model 806" is primary element, operating relay circuit to initiate an oscillatory action with frequency proportional to input. Counter registers number of cycles to provide a running time-integral of input. Application include: Light integration (using photocell); d-c. ampere-hour integration from low-potential shunts; watt-hour integration using thermal converters; total radiation integration using thermopiles; integration of nuclear radiation in combination with Geiger counters or ionization chambers; integration of magnitudes measured by changes in transmit-

Check These Outstanding Features of the New

No. 2700 Pressure Controllers

Providing Precise Response and Proportional Control at Moderate Cost



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ted light, such as totalization of opaque particles suspended in liquids flowing thorugh pipes at a constant rate. Unit is chassis-mounted and enclosed in a cast aluminum weatherproof case. Unlimited service life may be expected, according to manufacturer, with routine vacuum tube replacements only at about 2,000 service hour intervals.—*Weston Electrical Instrument Corp., 614 Frelinghuysen Ave., Newark 5, N. J.*

Mention No. 416 when filling out card

Coating-thickness Gage

New "Coatingage" directly and rapidly indicates thickness of non-magnetic coatings on iron or steel, without damage to coating. Two concentric scales cover a range of 0.0001 in. to 0.5 in. Self-contained battery power supply permits field as well as laboratory or production-line uses. "Coatingage" head contains a coil connected to a bridge circuit. Coating thickness is measured by effect of changes in reluctance of magnetic circuit. When coil is in direct contact with base metal, bridge is balanced for zero thickness. An increase in gap between coil and base metal unbalances bridge and causes current to flow through indicating microammeter. Luggage-type carrying case is 8 x 9 x 6 in. Outfit weighs 10 lbs. Thickness readings are within 10 percent of actual thickness.—*Branson Instruments, Inc., 436 Fairfield Avenue, Stamford, Conn.*

Mention No. 417 when filling out card

Resistance Thermometer Bulb

New resistance thermometer is said to provide fast response: 2.5 sec. for 63 percent change. It can be used at temperatures up to 1,000 deg. C. Furnished with platinum or nickel element, in stainless steel or brass casing. Ambient resistance from 10 to 100 ohms.—*Danco Instruments, Inc., P. O. Box 387, Huntington, N. Y.*

Mention No. 418 when filling out card

Surface Thermometers

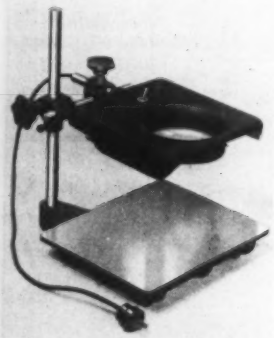
New resistance thermometers are designed for applications where it is more convenient to measure temperature at surface (of a tank, pipe line, etc.) than to insert a thermometer through a special fitting. Unit consists of a strip of flexible material wound with wire and covered on both sides with thin mica. Unit is 0.5 in. wide and 2 in. long. Three flexible silver leads are provided for connection to indicator or controller of any make. Unit can be attached to metal tank or pipe with suitable cement. If it is covered with asbestos or other insulation, temperature indicated should

be that of liquid in tank. New thermometers are said to be ideal for indication or control of temperature of dies for plastics. They are available in resistance values of 100 or 50 ohms at the ice point. Range up to 900 deg. F.—*Paul G. Weiller, 95 Broad Street, New York 4, N. Y.*

Mention No. 419 when filling out card

Layout and Inspection Plate

New precision ground plate is 11 x 9 in.; is cross-ribbed on underside for rigidity and has illuminated magnifier,



adjustable to any angle, and any height up to 10 in. Magnifier has 4.5 in. diameter specially-ground glass, with 25-watt tubular lamp on each side of glass. Lamps are shielded to direct rays onto work. No wrenches are required for adjustment of magnifier holder. Vertical position on post is maintained by small hand wheel. Collar with knurled set screw provides additional support. Unit is designed for instrument makers, laboratory technicians and others doing precision work.—*All American Tool & Mfg. Co., 1014 W. Fullerton Ave., Chicago 14, Ill.*

Mention No. 420 when filling out card

Refractometer

New refractometer for testing and controlling quality of chemicals, foods, and oils is portable electrically-illuminated instrument which is said to afford

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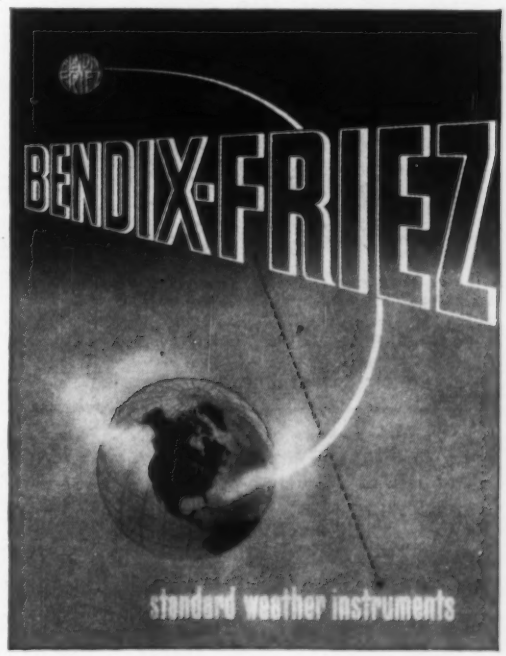

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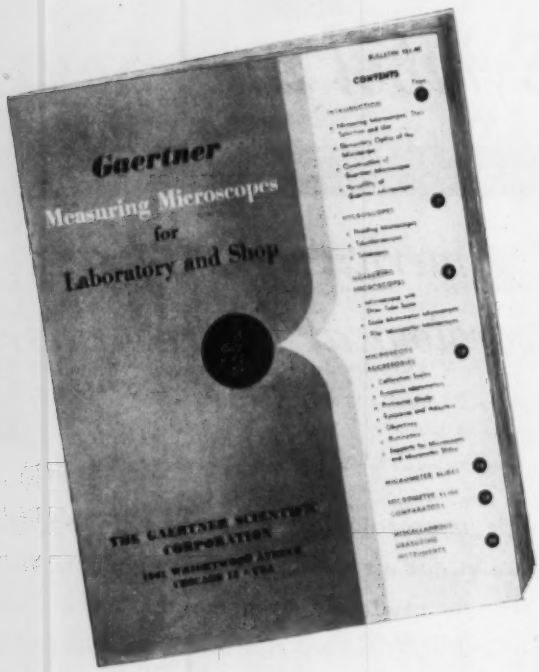

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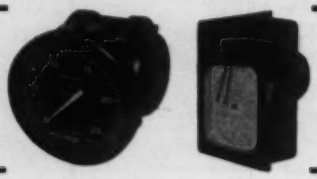
NEW BARTON FLOW METERS

MODEL 200 DIFFERENTIAL PRESSURE INDICATOR



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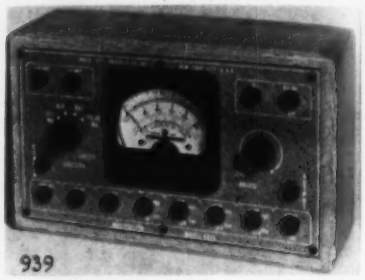
accurate refractive index readi[ng]s in less time than was possible with [pre]vious instruments. Detachable pris[m] system may be removed and re[pla]ced quickly with duplicate set to avoi[d] lay-offs, should repairs become nece[ssa]ry. (Previous models required factory [ser]vicing, involving several weeks d[el]ay.) Other features include built-in, [cor]rosion-free glass scale, dust-proof ho[us]ing and illumination system, and stati[on]ery eyepieces.—*Bausch & Lomb Optica[l] Co., Rochester 2, N. Y.*

Mention No. 421 when filling out card

Multi-purpose Electrical Tester

New "Model 447A Multitester" is a streamlined version of "Model 447," lighter-weight because of magnesium



panel and new battery arrangement. Ohmmeter circuit has been simplified so as to have same over-all coverage with only one unit cell and an improved battery holder. Gold-plated copper oxide rectifier with excellent current-density characteristic gives improved performance for measurement of a-c. and output voltages. Provision is made for extending ohmmeter range to 10 megohms by using an external battery—*Radio City Products Co., 152 W. 25th Street, New York 1, N. Y.*

Mention No. 422 when filling out card

Cylinder-block Gaging Machine

New cylinder-block gaging "Precisionaire" checks each bore in V-8 motor block at four different points and op-

erator manually stamps classification for proper assembly. Cylinder block comes on a roller conveyor, moves into position on a turntable, is locked in proper locating position. Operator then lowers the four gaging spindles into cylinder bores by pressing "down" button to start inspection operation. Each gaging spindle has four sets of air jets. Floats in 16 glass tubes indicate results. By turning a handle, operator rotates spindles 180 deg. and obtains a full

360 deg. check for out-of-round. Classification is in steps of 0.00025 in. Operator stamps this information on block with symbols, using a manually-operated device.—*The Sheffield Corp., Dayton* 1,

Mention No. 423 when filling out card

Sweep Signal Generator

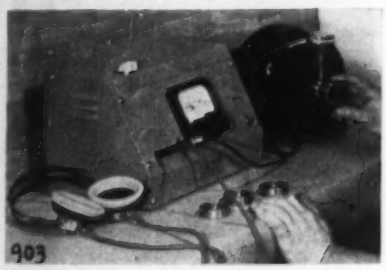
New "Series E-400" wide-range sweep-signal generator offers wide- and narrow-band sweep selection for positive FM and TV alignment and service. Frequency coverage from 2 to 240 Mc. in five bands without skip; continuous

narrow and wide band sweep direct reading from 0-1 Mc. and 0-10 Mc. Direct-reading, turned-aluminum tuning dial with about 6 ft. of easy-reading, 2-color etched scales is incorporated. Also included is direct-reading vernier scale, reading to one part in 1500 for critical applications. Terminated RG-U type co-axial rf. output cable provides for non-reactive injection of test signals, with HI-LO, plus open line impedance for utmost flexibility of application. External deviation input terminals offer direct facility for sweep operation at any desired frequency. Unit measures approx. 10.5 x 12 x 6 inches.—*Precision Apparatus Co., Inc., 92-27 Horace Harding Blvd., Elmhurst, L. I., N. Y.*

Mention No. 424 when filling out card

Vibration Tester

New "Sono-Probe" is an electrical amplifier whose input is vibration or noise picked up by contact microphone; is said to open whole new field of simple, economical vibration detection and noise analysis. Long metal probe of



microphone (alternate probe of Bakelite is provided for use around electrical equipment) is placed in contact with source of vibration. Because it is insensitive to airborne sounds, operator confines investigation to object touched by probe. Earphones are provided; also a decibel indicator and simple volume control for measurement of amount of

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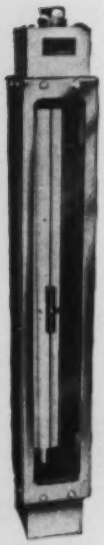

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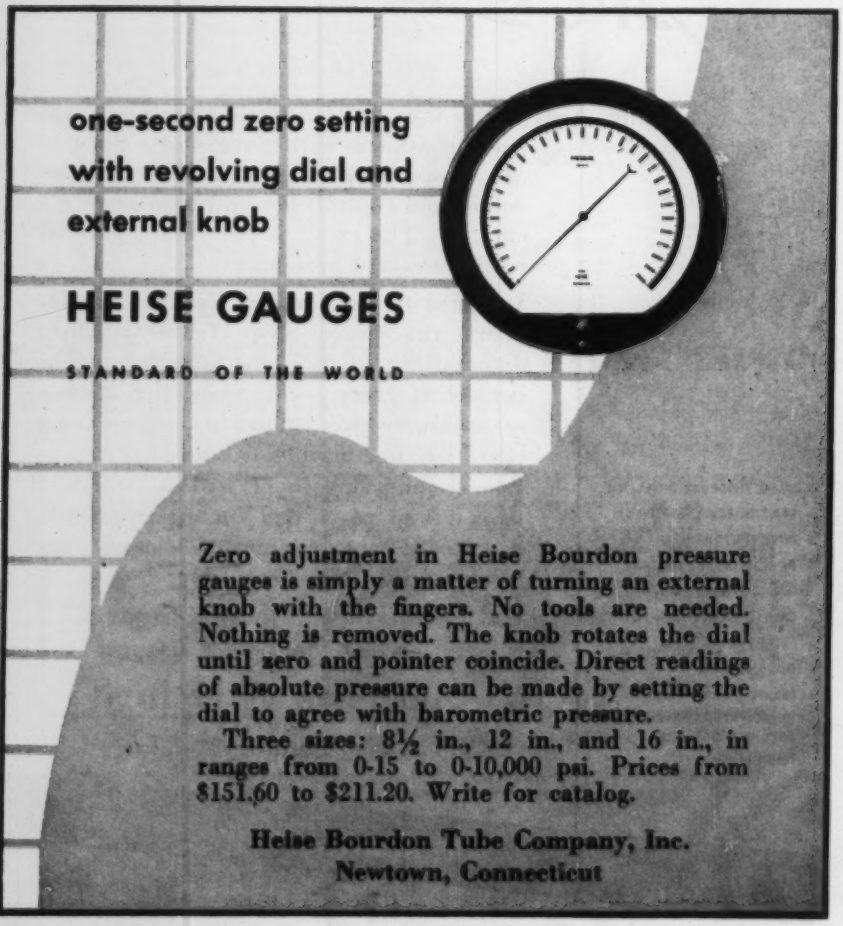
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Heise Bourdon Tube Company, Inc.
Newtown, Connecticut

vibration. Volume can be adjusted to acceptable standard decibel level for indicator and vibration level of any number of similiar parts or machines measured against it. No special training is needed to operate. It provides a "go no-go" or graded standard for inspecting parts or finished assemblies, maintenance and trouble shooting inspection, diagnosing motor ailments, checking sound insulations, shock mounts, gas expansion, water and air leaks, structural vibrations. Bench model operates on 115 volt a.c. Battery operated portable "Sono-Probe" is also available.—*Aircraft Electronics Associates, Inc., 1031 New Britain Ave., Hartford 10, Conn.*

Mention No. 425 when filling out card

Vacuum-Tube Voltmeter

New "Type AA-1" vacuum-tube voltmeter has calibrated range of 0.001 volt to 300 volts at all frequencies from 10

cycles to 1.5 Mc. It also is graduated in decibels, covering a range of minus 52 to plus 52 decibels from a reference level of 1 milliwatt at 600 ohms. Ten-position push-button switch permits any working range to be selected instantly without passing through intermediate ranges. Suitable for either portable or bench use, voltmeter has aluminum case with sloping front panel. Terminals for wires or standard banana jacks are provided; another set of standard banana jacks is furnished for taking off amplifier output. —*General Electric Co., Schenectady 5, N. Y.*

Mention No. 426 when filling out card

Manual Control Valve

New line of manually-actuated 4-position dual pressure valves, for use on accumulator-actuated high- and low-

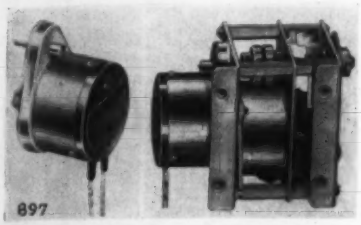
pressure presses, incorporate "Shear-Seal" principle. Lever, when moved through 90-deg. arc, permits separate introduction of low pressure and high pressure fluid. Throttling may be accomplished on low-pressure line and intermediate shut-off position is provided, permitting all flow to be stopped with minimum of handle motion. Furnished

in 4 sizes from 0.75 to 2 in. N.P.T., all for pressures to 7000 psi. All parts in contact with fluid are #416 stainless steel. *Saval, Inc.*, 1915 *East 51st St., Los Angeles* 11, *Calif.*

Mention No. 427 when filling out card

D-c. Motors, Timers

New d-c. timers and motors include "9200 Series" d-c. motor which is a low-voltage permanent-magnet type said to feature uniform torque and speed characteristics without use of a mechanical governor. Alnico magnet

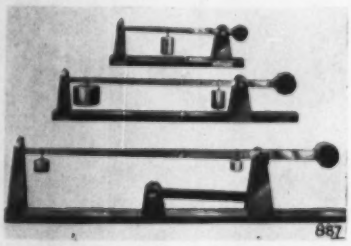


within aluminum rotor is said to assure lasting field flux; two long-lasting silver-graphite brushes supply armature current. Motors are reversible, lubricated for life, totally-enclosed, compact and lightweight. Basic motor has speed of 900 rpm. at 6 volts d.c.; wide range of output speeds is offered with standard gear trains, and motor may be built to operate on dc. as high as 115 volts. "5148 and 5149 Series" automatic reset timers utilize maker's "9800 series d-c. motors coupled to magnetically-operated clutch. They are said to give almost instantaneous resetting; are recommended for either time delay or interval timing by connecting load to proper side of double-throw switch. Clutch action is claimed to be positive. Totally-enclosed switch is rated at 10 amps, 28 volts d.c.; increased amperage is obtainable with decreased voltage ratings. "Series 5148" timer is non-adjustable; can be furnished with wide choice of time delays or intervals. "Series 5149" is adjustable over wide range of timing intervals. Both series are subject to inherent variations in timing due to effect of changes in voltage and temperature. — *Haydon Mfg. Co., Inc., Torrington, Conn.*

Mention No. 428 when filling out card

Torque Measurement Stands

Two new models of "Trutorq" beam stands, "Model SDB-10," and "Model SDB-50" provide complete range of



torque measurements from 0 to 50 inch-ounces up to 25 foot-pounds. "Model SDB-10" has range of 0 to 50 inch-ounces, calibrated in increments of 0.5 inch-ounce; "Model SDB-50" covers from 0 to 50 foot-pounds in increments of 0.25 or 0.5 foot-pounds. All models have ball-bearing beam fulcrum and are

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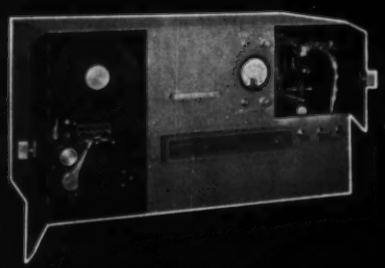

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— Temperatures —

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- Temperature compensated tuning fork — discharge lamp imposing sharply defined .01 second lines with heavy .1 second lines.
- Daylight loading 200 ft. storage and takeup magazines — accommodate 2" to 8" paper widths.
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Write for Catalog No. 101-A, descriptive of this and other models of Oscillographs.

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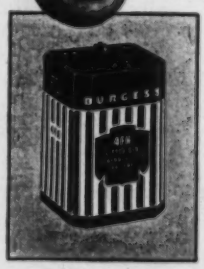

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accurate to the fraction of unit of measurement for each model. Each instrument is individually calibrated. Special models are also made for measurements up to 150 foot-pounds; special adaptors for tools can also be furnished.—*Airdraulics Engineering, Inc., New Canaan, Conn.*

Mention No. 429 when filling out card

Radiation Survey Meter

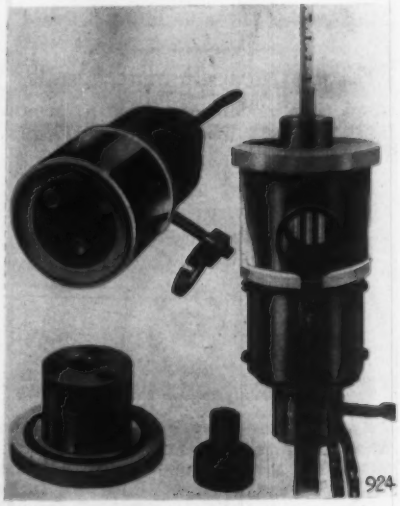
New "Model 102" Geiger counter permits measurement of low-energy beta particles and alpha particles as well as

gamma and x-rays. Unit contains thin-end mica window counter with 1.5 mg. per sq. cm. window which enables it to detect Carbon 14 and other radio-active tracers. Tube is self-quenching with Geiger threshold at 825 plus-or-minus 25 volts and 200 volt plateau. Tube is mounted inside specially-designed probe which enables instrument to distinguish between alpha, beta, and gamma radiations. Assembly and weatherproof cable is mounted on box 5.25 x 6.5 x 4.5 in. and weighs about 7 lbs. — *Precision Radiation Instruments, Inc.*, 1101 *N. Paulina St., Chicago* 22, *Ill.*

Mention No. 430 when filling out card

Melting-point Apparatus

New "Vanderkamp Melt-Pointer" for determining melting points of chemicals, waxes, fats, etc., has solid copper block



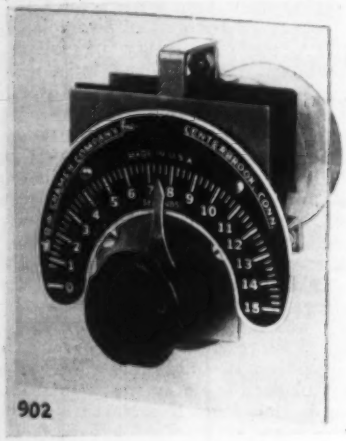
with three holes that fit over three 50-watt, 110 volt cartridge-type heaters. Heaters project from brass base and instrument is used with variable

transformer, thermometer and capillaries to heat and observe exact melting point. Samples are illuminated from below and capillaries are observed through adjustable magnifying lens. Range is up to 400 deg. C. No liquids or stirring are required and block can be removed for rapid cooling.—*Scientific Glass Apparatus Co., 49 Ackerman St., Bloomfield, N. J.*

Mention No. 431 when filling out card

Interval Timer

New "Type IG" interval timer, for use when electrical equipment is to be manually turned on, run for a pre-set time and stopped automatically, operates one or two s-p.d-t. switches and returns to original position at end of



pre-determined time interval. Timers, without external housings, are especially made for built-in applications in microfilming equipment, therapeutic machines, extractors, ovens, etc. Self-starting synchronous motor operates enclosed dust-tight snap switch through a cam and actuating arm. Manual setting of pointer closes motor circuit and starts timing. Friction clutch in motor gear train permits shutting off timer or extending timing cycle manually during operation. "Hold position," optional on two-pole "Model IG2," permits turning on load circuit without starting timing cycle. Eleven time ranges: from 15 secs. to 24 hours. Unit is available for voltages from 6 to 230 volts.—*The R. W. Cramer Co., Centerbrook, Conn.*

Mention No. 432 when filling out card

Bearing Temperature Alarm System

New bearing temperature alarm is an electronic resistance thermometer system which actuates signal lights or an audible alarm or both. Resistance-thermometer bulbs are Weiller vibration-proof fused-in-glass type (see our May '48 issue, p. 417; Sept. '48, p. 806, Jan. '49, p. 43). They are corrosion-proof. Neither oil nor water will attack them. In order to obtain intimate contact with babbit or bronze bushing or lining, and to prevent heat transmission delays which make an alarm system uncertain, wound part of unit is less than 0.25 in. long and imbedded in a solid copper slug 0.320 in. in diameter; metal is in direct contact with glass and all air spaces have been eliminated. Thus,

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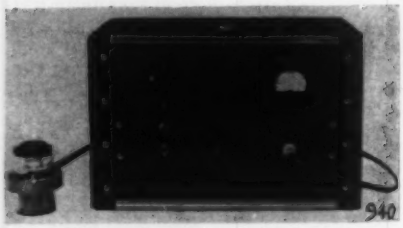
there is a fully solid path for heat from wire to outside. Copper slug is introduced through a suitable opening in body of bearing and can be pressed against lining by a gland and spring. In babbitt bearings, slug can be cast-in when lining is cast. Mounting details vary with construction of bearing. Unit has two or three leads, depending on type of instrument associated with it. Up to thirty bulbs can be operated with a single alarm. Cycling System: To operate a light signal alarm from a number of thermometer units, latter are connected in sequence with alarm units. When one signal light is on, indicating danger in one particular bearing, it stays on after switch passes on to next unit; it goes out only when this bearing's temperature drops again below danger point. This is accomplished, by operating each light with a latch-in relay; rotary switch unit of two-pole variety. (A stepping relay of telephone switchboard type indexed by a motor-driven cam switch serves this purpose well). Switch unit operates continuously, stepping ahead every two seconds. During each two-second interval, one unit is connected to alarm. If bearing is too hot, control closes a latching relay which stays closed when switch steps to next position and signal remains on, as alarm output relay is connected sp.-d-t. If bearing temperature has dropped again when switch passes over same contact, release coil of latch-in relay is energized; relay drops out and signal goes out. Control can be a standard "Resireg" electronic temperature control with fixed temperature setting; power relay omitted.—*Paul G. Weiller, 95 Broad St., New York 4, N. Y.*

Mention No. 433 when filling out card

Ultrasonic Generator

New "Type CL" (clinical-laboratory) ultrasonic generator has special convertible transducer for transmitting high-frequency vibrations to skin of patient, or to specimen of material under treatment. Transducer is connected to



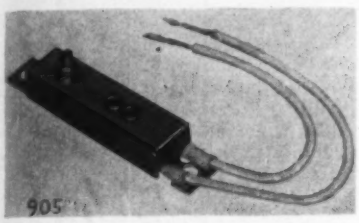
generating unit by a coaxial cable carrying less than 100 volts h-f. current. Base of transducer comprises a transparent Lucite tube, surrounded by a ring (containing primary winding) from which projects a handle, with connecting cable. Inside this tube is secondary winding. Crystal is mounted above secondary coil upon nylon rods, between Bakelite and glass disks. Tube is closed by a cap containing a Bakelite diaphragm 0.01-in. thick, mechanically connected with vibrating crystal by oil which fills entire assembly. This diaphragm, placed against skin or specimen, effectively transmits ultrasonic vibrations, generated by the crystal, which is 1.5 in. in diameter and from approx. 0.12 to 0.25 in. thick, depending upon frequency desired. A second Lucite

tube may be screwed to top of base assembly and filled with oil into which a test tube or other vessel containing either solid or liquid material to be treated may be immersed. This feature of convertibility makes equipment suitable for clinical or laboratory work. Generating unit operates from standard 115-volt 60-cycle supply, uses full-wave rectification with adequate filtering. Self-excited oscillator is coupled to crystal circuit and is frequency-controlled by it. Thus, oscillator frequency is prevented from drifting out of phase with natural period of crystal, assuring constant and maximum energy delivery. Power control is adjustable, and is measured in crystal circuit. Standard frequency of generator is 450 kc., with alternate crystal and coil available for quick conversion to 900 kc. (Other frequencies available on special order).—*Ultrasonic Engineering Co., Dept. 30, Main St., and Eighth Ave., Maywood, Ill.*

Mention No. 434 when filling out card

Strip-Type Shockproof Thermostat

New housed strip-type thermostat is shockproof in that all live metal parts are shielded and provided with nickel



stranded Fiberglas-insulated lead wire. Thermal responding element is insulated from switch and carries no current. Other parts are made of heat-resisting alloy metals, mica insulated throughout. Unit is provided with heavy-duty heat-dissipating electrolytic silver contacts. Maximum operating temperature 650F. Self-locking adjustment screw provides more positive closer and quicker adjustment. Can also be supplied with heat-range limit adjustment shaft. Rated at 1500 watts, 115-230 volts a.c. Weight, 2 oz.—*The George Ulanet Co., 416 Market St., Newark 5, N. J.*

Mention No. 435 when filling out card

Noise and Vibration Measuring System

New "Sono-Probe" noise and vibration instrument has one large illuminated scale and is particularly recommended for use by production workers

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Example 1.5-5-15-50-150-1500 volts at 1000 ohms per volt, DC to 10 KC.

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as a "go-no-go" device in testing objects ranging from watches to large bearings. Instrument includes contact microphone sensitive to vibration of probe tip, and three stage amplifier, variable up to 90 db. Probe has frequency response of 100 to 20,000 cps. and amplifier response is plus or minus 1 db. from 60 to 20,000 cps. Headphones are provided for audible checks, also leads for oscilloscope studies. — *Aircraft Electronics Associates, 1031 New Britain Ave., Hartford 10, Conn.*

Mention No. 436 when filling out card

A-c.-powered Timer

New "Minitrol" is a 60-minute-limit timer suitable for timing photographic processes, x-ray and physiotherapy

treatments, laboratory techniques, plastic molding, process timing, etc. Synchronous movement and continuous electric alarm buzzer are built by Telechron Inc. Complete unit fits comfortably into one hand. Available in red, green or ivory, complete with 6-foot plug-in-cord.—*Wil-Mar Company, Box 1, Natick, Mass.*

Mention No. 437 when filling out card

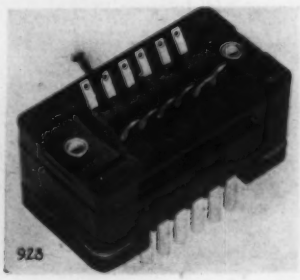
Constant Temperature and Humidity Cabinet

New "Aire-Regulator" cabinet permits holding constant temperatures in range between room temperature and 140F. and humidity from 30 to 98 percent. Operation is automatic and needs little attention from operator. Temperature is held within 1 deg. F.; humidity 1 deg. F. wet-bulb.—*Food Technology, Inc., at 5903 Northwest Highway, Chicago 31, Ill.*

Mention No. 438 when filling out card

Terminal Connectors

New "RTC" series of connectors for quick disconnects on electrical installations feature low separation force; simplicity of mounting on chassis; mois-



ture-drain holes in receptable section; provisions in plug section for lacing down wires to plug after soldering to contacts; two types of terminals—crimp-on and soldered. Plug shells are phenolic. Five sizes have contacts for 18 and 20 wire; 12 to 36 contact combinations. Mechanical spacing is 0.094 in.; minimum flashover of 2500 volts and recommended amperage of 5 amps. — *Cannon Electric Development Co., 3209 Humboldt St., Los Angeles 31, Calif.*

Mention No. 439 when filling out card

Fixed-frequency FM Tuners

Three new fixed-frequency FM tuners for use in 88-108-Mc. band are crystal-controlled; are adapted to relay reception, monitoring, etc. "Model RP-23" is a straightforward FM Tuner using Armstrong circuit with dual lim-

iters. Signal input for 20 db quieting is 10 microvolts with response within 1 db from 30 cycles to 17 kc. Audio stage provides 1 volt RMS output with quieting signal. Antenna input is 72 or 300 ohms. "Model RP-24" consists of same tuner plus relay circuits which operate on tones of from 15 to 20 kc. received from transmitter and which select in sequence two preset audio volume levels which may be manually adjusted from zero to full output. "Model RP-25" (illustrated) utilizes same tuner but has two relay circuits permitting audio level selection as in "RP-24" and also permits turning audio "on" or "off" as required. Relay operations are controlled by transmitted tones of different frequency and are, therefore, independent. In "RP-24" and "RP-25," relay circuits are preset to operate at 15, 17.5 or 20 kc. as specified by customer.—*Browning Laboratories, Inc., Winchester, Mass.*

Mention No. 440 when filling out card

Heating Jackets With Safety Thermostats

New line of "Gyco Heating Jackets" features addition of a small thermostat in circuit within insulation. This thermostat, permanently sealed against vapors or moisture, automatically opens circuit when jacket temperature reach-

$1,500 inventory abolished — at a cost of $4.46!

With more than 700 vacuum tubes needed by industry, a tube distributor would find profits consumed by 100% inventories. But by ordering tubes as needed via Air Express, he holds stocks to 25%. Example: Orders **$1,500** tube at **9 A.M.** from supplier **900** miles away. Delivered to customer **6 P.M.** same day. **16 lbs.**: cost, **$4.46.**

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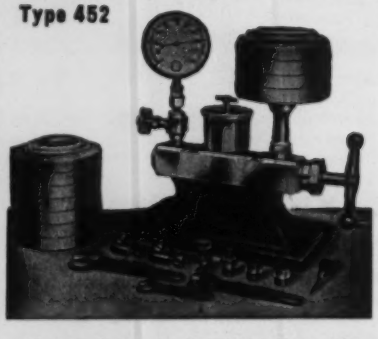

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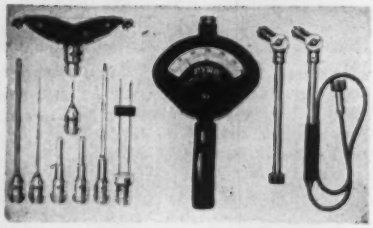

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es approx. 370C., thereby preventing thermal strain on heated vessel. Life of heating elements is greatly prolonged, since they always operate at a safe level well below glow point. New jackets retain other features described in detail in our Jan. '47 issue, pages 79-80. —*Scientific Glass Apparatus Co., Inc., Bloomfield, N. J.*

Mention No. 441 when filling out card

Flame Failure Safeguard

New "Fireye System FF-3," for flame failure protection of semi-automatic and manually ignited industrial

oil burners, includes photoelectric scanner "Type 45PH5" and control "Type 24QJ5." Scanner has phototube and vacuum tube amplifier housed in dust-tight aluminum case; is mounted on the burner mounting plate. When flame fails "Fireye" instantly signals control which cuts off fuel supply and sounds alarm. Control consists of two relays and power transformer housed in dust-tight steel case, includes safety start circuit which prevents burner from cycling if flame is detected or simulated prior to ignition.—*Combustion Control Corp., 77 Broadway, Cambridge 42, Mass.*

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Temperature Controller

New "Model 600 Temcometer," like previous models, is a stepless input controller for use in regulating temper-

atures of electrically-heated furnaces, pots, etc., but is designed for through-panel mounting; is 3.5 in. in diameter and extends 4 in. behind mounting panel. Dial is graduated in percent time "on" and stepless regulation between 5 and 100 percent is provided. Instrument maintains constant watt-hour input and even temperature in connected equipment, regardless of fluctuations in line voltage. For loads over 6 amperes, 115 volts, or 3 amperes, 230 volts, instrument is to be connected to a relay of proper capacity for load.—*Thermo Electric Mfg. Co., 496 W. Locust St., Dubuque, Iowa.*

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OUTPUT IMPEDANCE: 50 ohms.

MODULATION: SINEWAVE: 0—30%, 400, 1000 or 2500 cycles. PULSE: Repetition—60 to 100,000 cycles. Width—1 to 50 microseconds. Delay—0 to 50 microseconds. Sync. input—amplifier and control. Sync. output—either polarity.

DIMENSIONS: Width 26", Height 12", Depth 10".

WEIGHT: 125 pounds including external line voltage regulator.

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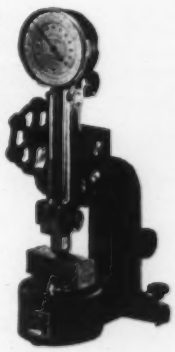

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INSTRUMENTS ON THE MARCH

Porcelain Enamel Adherence Tester

WASHINGTON, D. C. — Porcelain enamel must adhere well to the base metal in order to perform satisfactorily in service. The degree of adherence has long been considered an important criterion of the quality of an enamel ground coat. An instrument by which this property may be evaluated through a simple measurement has been designed by Allen C. Francisco, Research Associate of the Porcelain Enamel Institute at the National Bureau of Standards. The apparatus, designed to measure enamel-to-metal adherence electrically, promises to replace the visual estimate method now commonly used and appears adaptable to other types of nonplastic coatings.

The evaluation of adherence is usually made by a visual estimate of the amount of bare metal exposed within a given area on an enameled metal specimen after it has been deformed in a specified manner. The deformation is effected by placing the specimen over a circular die and applying force to a spherical head centered over the die. The elastic limit of the base metal is exceeded and a permanent depression of predetermined dimensions is formed in the specimen. The estimated amount of bare metal, expressed as a percentage of the test area, is used to place the enamel in one of several broad classifications.

Normally, a porcelain enamel coating is an electrical insulator. The basic principle of the new instrument depends on the completion of an electric circuit through the metal of the deformed specimen to a steel probe touching the test area. By using a large number of probes, and counting the number which conduct a current during the test, the area which has been exposed can be measured.

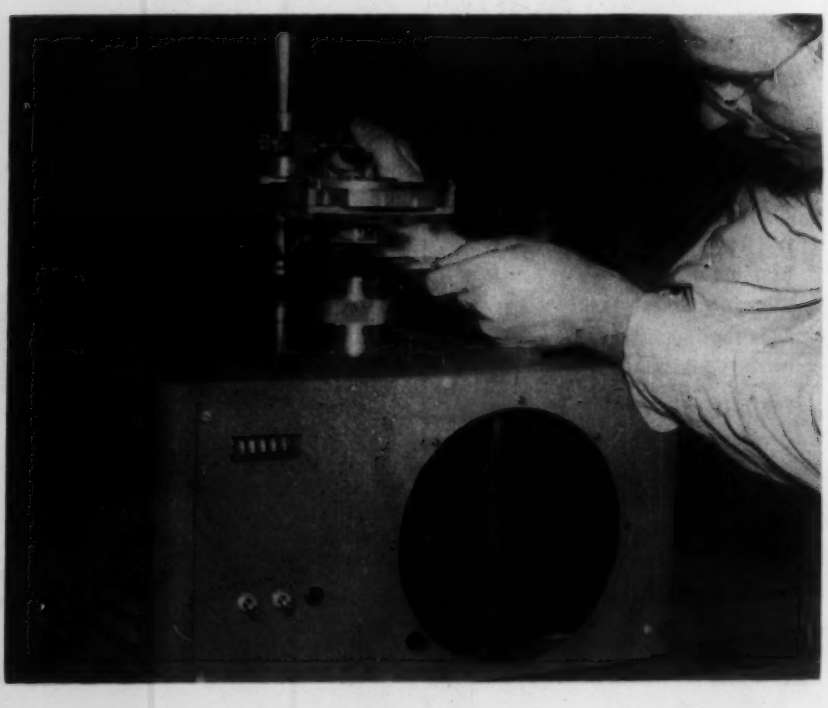
The instrument consists of a stand, test head and control cabinet. For use on large, flat areas, the stand may be placed on the specimen and the head lowered to make contact with the surface on which the stand is placed.

The test head comprises a plastic block with 169 holes arranged in a hexagonal close-packed pattern (distance between centers 0.1 inch). Each hole is fitted with a probe-bearing assembly which is free to move vertically against a beryllium copper spring. This spring makes an electrical contact between the probe assembly and a wire connected to an individual segment of the selector switch located in the control cabinet.

The steel probes can be lowered onto slightly different locations of the same test deformation by pivoting the plastic block from one to another of five stop positions spaced 7.5 degrees apart since the pivot of the test head is located eccentrically with respect to the test deformation, the center of rotation is different from that of the concentric circles of enamel and bare metal generally found on the deformed area. In this way the possibility of any one probe following the same circular fracture is minimized, and the multiple count for the five positions increases the precision of the measurement.

The control cabinet contains a power supply, relay, selector switch, and magnetic counter. A synchronous motor drives the selector switch, and the circuit through each probe is tested individually as the arm rotates. The test cycle, started manually, is stopped automatically after the last circuit is tested. For each needle which touches bare metal, the relay actuates the counter.

The number recorded on the counter may be used for direct comparison of two specimens or, if desired, the exposed and coated portions of the test area may be readily computed, and the coated fraction used as an index of adherence.



Gage Lab. at Stanford Research Institute

(Special report for *Instruments*)

STANFORD, Calif.—The only western Precision Gage Laboratory north of Los Angeles, and one of two in the entire West Coast region, began operation on February 24 at Stanford Research Institute, according to an announcement by Dr. J. E. Hobson, exective director of the Insitute, which is a non-profit applied research organization.

The facilities, which include a quarter of a million dollars' worth of high-precision instruments, are to be made available to industrial firms, college science sections, and individuals. In making the announcement, Dr. Hobson said: "The convenient calibration of precision measuring standards, instruments, and manufactured components is one of the vital necessities of any industrial area. We consider ourselves most fortunate in having obtained all of the instruments needed for general industrial and research purposes." He pointed out that the facilities of the laboratory are unique in the Northern California region, and that they are non-existent in Oregon, Washington, Idaho, Wyoming, Montana, Nevada, and Utah.

Most of the equipment is under contract from the Army Ordnance Department, which closed its San Francisco district gage laboratories several years ago. Nominal fees will be charged for use of the equipment, on a cost-incurred basis. Lt. Col. J. G. Shinkle has indicated that the San Francisco District will continue to use the equipment. He also pointed to the advantage of a centrally-located laboratory here which will make it unnecessary to send industrial

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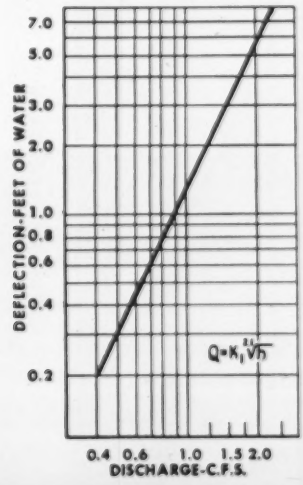
Head Capacity Curve for Type V Flow Tube, Differential produced by viscosity forces.



Log Plot of Head Capacity Curve.

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Now! The new Bethlehem Flow Tube—for large savings in power . . . higher product quality . . . large installation savings—offers proof positive of consistent accuracy.

In calibration tests conducted by an independent hydraulic laboratory—one of the foremost in the country—the Bethlehem Flow Tube held its high accuracy to the limit of the testing apparatus. Discharge plotted against head proved that differential head is in all cases proportional to a constant power of velocity . . . that discharge coefficient is constant over *an 8:1 range of discharge.*

Add to this: one pipe diameter length . . . negligible resistance to flow in most installations . . . minimum straight run limitations after elbows and similar fittings . . . measurement of gases without consideration of compressibility factors and the Bethlehem Flow Tube becomes an outstanding improvement wherever it is necessary to measure or control fluid flow

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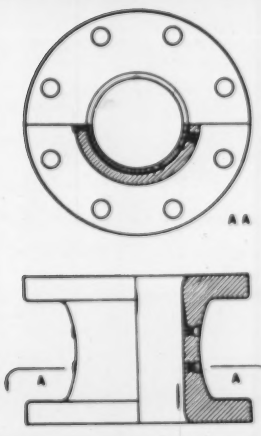
*GENTILE PATENTS



Cross-Section of Type V Flow Tube. Pat. No. 2,260,019. Other patents pending.

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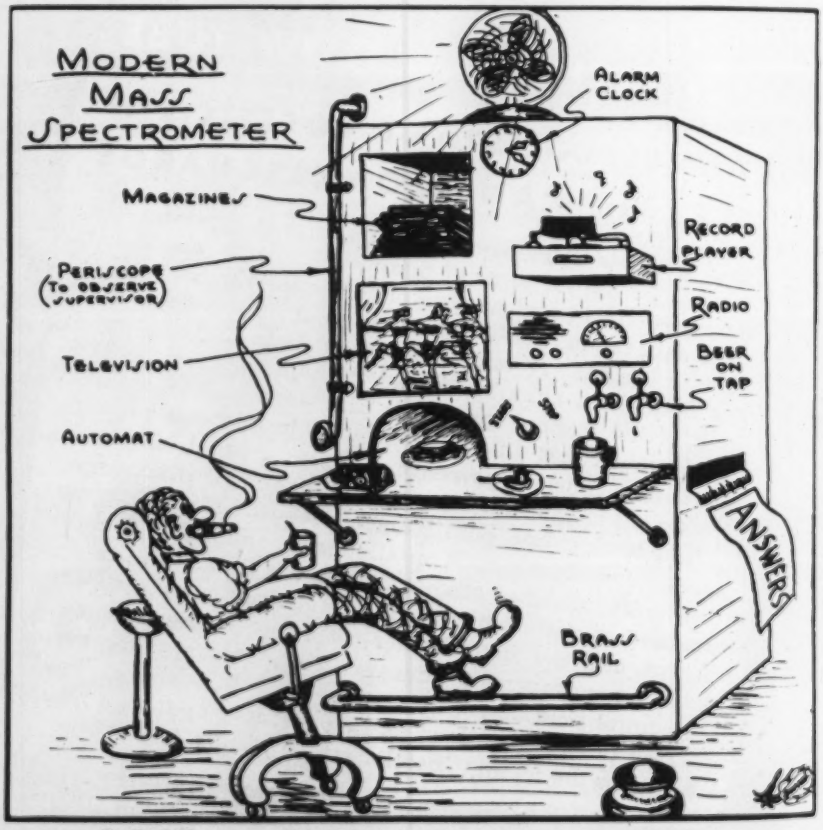
standards to the East for periodic checking.

The laboratory contains an Electrolimit comparator, used with gage blocks to check the accuracy of industrial gages, fixtures, etc. Among the largest instruments is a Pratt & Whitney 80-inch standard measuring machine for calibrating secondary standards used in industry. Three supermicrometers, available for average-size work, have a measuring accuracy of fifty millionths of an inch. Two large optical comparators magnify objects up to 100 times for checking contours and angles. The latest-model Magnaflux is used for detecting flaws in metal. A Rockwell tester is used to determine the degree of hardness of a material.

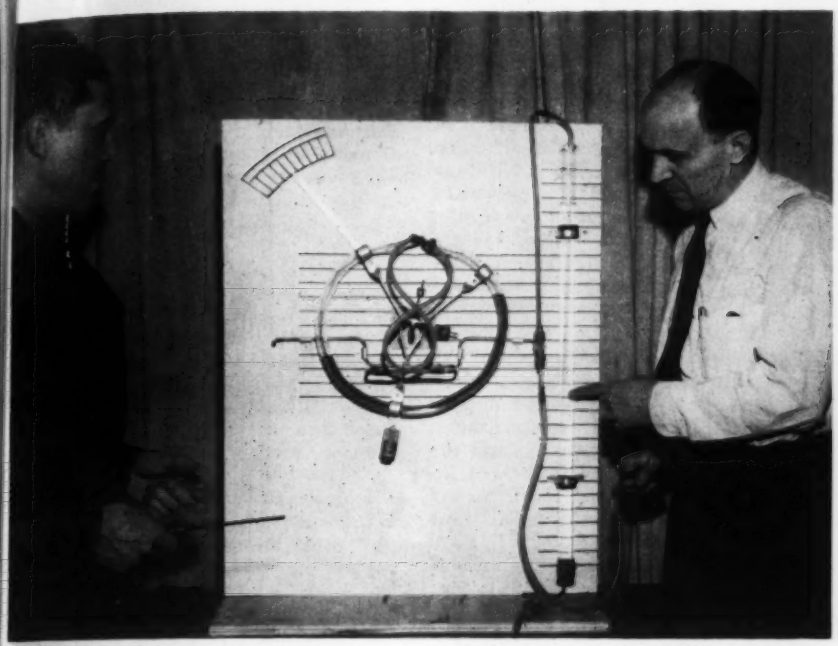
Among the 2000 other items are optical flats and their accessories. The equipment also includes several master sets of precision gage blocks—the

Highly specialized glass blowers at Stanford Research Institute make instruments needed by the staff members of the various departments.

*Instru*Merriment



By K. E. Burmaster, Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.



Richland Instrument Men Show Metering Principle

To the Editor of *Instruments*:

At a recent meeting of the Richland Section of I.S.A. two members of the group, A. W. Hildebrandt (left) and C. M. Wells (right), demonstrated the Ring Balance Meter through the method shown in the accompanying photo.

The ring, made of one-inch glass tubing, filled with No. 3 red oil, gave a vivid account of the sealing fluid's action when pressure was applied to the dip leg emerged in the water column at the right. For demonstrating purposes the air pressure was supplied with a large atomizer bulb.

The thought occurred to us that others may be interested in this method of demonstrating this instrument. You have our permission to publish it in *Instruments*.

CLARENCE J. WEICHEL,
Publicity Committee Chairman.

"heart" of a gage laboratory. The sets at SRI include Johansson, Hoke, and Van Keuren makes. They will be tested for indication of wear every six months by the National Bureau of Standards Dust-free air is held at a constant temperature of 68 degrees Fahrenheit and a humidity of 35 percent, most favorable conditions for precise gage measurements.

New Flow Calorimeter

WASHINGTON, D. C.—A new flow calorimeter for more accurate measurements of the specific heats of gases has been developed by R. B. Scott of the National Bureau of Standards. This apparatus was constructed in connection with a program sponsored jointly by the Bureau and the Office of Rubber Reserve for the determination of the thermodynamic properties of materials involved in the production of synthetic rubber and related substances. The greater precision of the new instrument is chiefly due to the almost complete elimination of heat leaks by various features of design. The small heat capacity of the calorimeter also results in improved accuracy through the easier and more rapid attainment of a constant temperature distribution within the system, since only under conditions of steady temperature is an accurate measurement possible.

Accurate data on specific heats and other thermal properties of gases are of value to chemical industry, where they are used in calculations that predict the results of chemical reactions.

Specific heat is most simply obtained experimentally by adding a measured amount of heat to a fixed mass and recording the temperature rise. However, the heat capacity per unit volume of a gas is so low that small accidental heat leaks are often comparable in size to the heat used in actually raising the temperature of the gas. Reduction of the ratio of heat loss or gain to heat input is thus one of the chief problems of gas calorimetry. In the calorimeter constructed at the National Bureau of Standards, this is accomplished by causing the gas to flow continuously at a uniform rate through an insulated chamber in which it is heated electrically. The heat capacity is then calculated from the heat input, the temperature rise of the gas, and the rate of flow. With gas calorimeters of this general type, a correction is usually made

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For photographic recording of d.c. or a.c. currents with "flat" frequency response to as high as 2500 cycles per second. Available in a wide range of natural frequencies, all having high factors of sensitivity and dynamic balance. Their tubular hermetically sealed construction insures long-lived dependability and ruggedness. Magnetic assemblies are constructed for 2, 4, 8, 12 and 14 element mounting.

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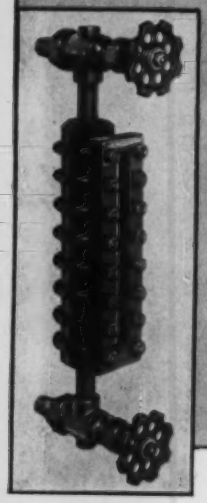
When Liquids Boil and Surge the new JERGUSON LARGE CHAMBER GAGE Will Give You A Level Reading



WHEN liquids boil and surge, and use of a coolant is undesirable, the New Jerguson Large Chamber Gage will give you a level reading.

Ordinary gages do not give sufficiently accurate readings on such liquids where the level fluctuates rapidly in the glass. With this new Jerguson, however, the gage chamber is of such large diameter that the level is not badly upset by the boiling action of the fluid. This makes it possible to get close level readings, the kind of readings you want for safety and accurate control.

Don't be satisfied any longer with gages that require you to *guess* at level readings. If liquids boil, install Jerguson Large Chamber Gages and *be sure.*

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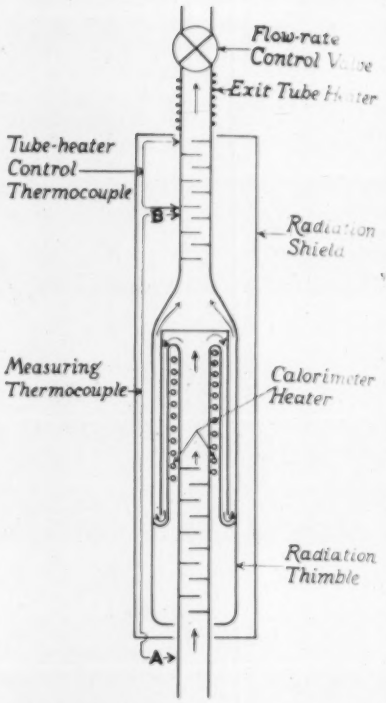
for heat leaks by making measurements at varying flow rates and extrapolating the apparent specific heats to infinite rate of flow, where such errors are negligible. In the new apparatus, however, special precautions have reduced heat leaks to such an extent that a correction for them is unnecessary. This advantage greatly lessens the number of necessary observations and also makes the results more trustworthy, since there are errors in calorimetric measurements that increase with increasing flow rate and cannot be removed by extrapolation to infinite flow.

Fig. 1 is a schematic diagram of the new calorimeter. The gas under study flows continuously at a constant rate through an insulated compartment, where it is heated electrically, and the specific heat is computed from heat input, temperature rise of the gas, and rate of flow. Entering the calorimeter at the bottom, the gas flows upward through the central calorimeter tube of Monel metal past a series of baffles, that act as radiation shields and also promote thermal equilibrium between the gas and the tube walls.



In the central part of the calorimeter the gas traverses a labyrinth about the calorimeter heater while its temperature is being raised. The labyrinth is

WHEN A FELLER NEEDS CONTROL

By Phil Putnam

Instruments pays $5.00 for each idea used. Sender's name and company affiliation will be acknowledged in the cartoon unless we are specifically requested not to do so. Address Cartoon Dep't, *Instruments*, 1125 Wolfendale St., Pittsburgh 12, Pa.

designed to provide an isothermal exterior surface on this part of the calorimeter. The metal radiation thimble extends this isothermal surface to a point very near to where the tube enters the copper radiation shield. Heat exchange by radiation is prevented by heating the shield to the temperature of the inner calorimeter wall with an electric heater, adjusted manually accordiig to thermocouple readings.

The rise in temperature of the gas is indicated by the measuring thermocouple. After its temperature has been raised, the gas passes upward again past a series of baffles and out through the flow-rate control valve. The exit tube heater serves to establish a zero temperature gradient in the upper part of the tube, thus reducing heat transfer along the tube.

The entire apparatus, except for the flow-rate control valve, is enclosed in a highly evacuated metal case (not shown) immersed in a constant-temperature bath. Before entering the calorimeter, the gas flows through a helical coil, in which it is brought to the temperature of the bath.

The accuracy of the apparatus was checked by measuring the specific heat of oxygen, which had previously been accurately calculated at the Bureau from the latest spectroscopic data for this gas. From a consideration of the data for oxygen, the probable error of the specific heats obtained with the calorimeter is estimated as 0.07 percent.

TECHNICAL SOCIETIES

ASME Spring Meeting

The 1949 Spring Meeting of the ASME, to be held May 2-4 at the Mohican Hotel, New London, Conn., will feature instrumentation papers including the following:

"Heat Conduction Errors in Temperature Measurement" by L. E. Smith, The Bristol Co.

"The High-speed Analog Applied in Industry" by G. A. Philbrick, Philbrick Researchers Inc.

"Man-Au-Trol Applications to Machine Tools" by L. J. Bandis, The Bullard Co.

"Automatic Electric Controls in Thread-grinder Design" by E. V. Flanders, Jones & Lamson Co.

"Need for Health Instruments in Nuclear Applications" by J. R. Martin, Kellex Corp.

"Available Health Instruments in Nuclear Applications" by A. O. Beckman, National Technical Labs.

Session on NON-DESTRUCTIVE TESTING: papers by H. H. Lester (Watertown Arsenal), J. L. Bly (Pratt & Whitney), Lewis Gold (Brown Univ.), C. H. Hastings (Watertown Arsenal).

SCMA

The April dinner meeting program of the Southern California Meter Association, at Rio Hondo Country Club, Thursday the 21st, will feature a presentation of activities at the Trona Plant of the American Potash and Chemical Co. Clifford H. Gest, plant process engineer, will speak on "Process Control of Trona Production." H. J. Bensinger, assistant sales manager, will offer a discussion of the various chemicals recovered from the brines of nearby Searles Lake, their properties and application.

Dinner will be served at 6:30 p. m. All interested parties are invited to attend this meeting.

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In order to obtain direct reading of color temperature it was necessary for the "Spectra" to incorporate an extremely sensitive microammeter that would read directly in degrees Kelvin. Because of Marion's recognized reputation for manufacturing extremely sensitive, trouble-free meters and instruments of this nature, Photo Research naturally turned to Marion for this key component.

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Vol. 4 — APRIL 1949 — No. 4

General News

ISA Executive Committee Meets in Chicago

The executive committee met in Chicago on March 6th with practically a full roster of members present. The various vice-presidents reported on the committees under their supervision. When compared with some of the earlier executive committee meetings, it has been my privilege to attend, this meeting seemed to prove that the adoption of the divisional organization plan last year was a wise move.

A new committee was set up with A. H. Shafer (Pittsburgh) as chairman to study society organization and planning. This committee will operate under vice-president Frost and will give its attention to long-range financial plans, plans for national meetings and study the growth of other societies in an effort to steer the ISA around whatever pitfalls may seem to lie ahead.

Convention Special

The Chicago Section is planning a convention special for the Toronto meeting, May 12-13. Possibly other sections may wish to investigate the possibility of air, rail or bus specials for this spring meeting.

Spring Meeting Hotel Reservations and Advance Registration

Hotel reservations for the ISA spring meeting, May 12-13, Royal York Hotel, Toronto, Ontario, Canada must be made before April 30. Registration may be made by writing to the National Office now.

Section News

ARUBA

At our Jan. 4th meeting, Mr. F. E. Griffin, Plant Superintendent of Lago Oil & Transport Co., Ltd., Aruba, gave a talk on "Advanced Business Management Program as given at the Harvard Graduate School of Business Administration." It was very interesting to learn the calibre of those who attend; the companies represented; the manner in which such a course is handled; some of the problems of the various companies and comparison of benefit plans. We came away from this meeting with a better appreciation of the Administration of any business. The president reported that the society was in receipt of a letter from the Government of the Territory of Curacao requesting a summary of the activities of our group for the years 1947 and 1948.

After the business portion of our Feb. 1st meeting the Program Committee introduced the five instructors who are to lecture during the ISA Electronics Course which is being sponsored by the section. A resume of the course was given listing time, place, dates, duration, text and reference material, construction tools and suggested Laboratory Kit. Each of the five instructors gave a five minute talk describing their experience and background as a means of introducing themselves to the group. The Program Committee accepted applications for the course from members and guests present. The Course was officially gotten under way on Feb. 7th and will run for 32 weeks.

Our March 1st business meeting was mostly taken up with discussion centered around the establishing of an amateur radio station for the Aruba Section, if and when governmental regulations will permit "Ham" operators in the area.

Our Speaker, Harry Irving, Taylor Instrument Co's., gave a talk on "Time as a Process Variable." He brought us up to date on the latest means of time control and gave us many examples of the use of time controls. His talk was very timely because it dealt with cost control which is a very active subject in our everyday business these days. He pointed out that time controllers and controllers in which time is a major factor have been widely accepted by industry for several reasons: 1) Improved quality — through greater uniformity, 2) Greater production — saving of time and physical effort, 3) Lower costs—through reduced waste and time savings, 4) Safety in hazardous processes — through completely automatic operation, 5) Changes in general attitude toward automatic control. This is the third year that Mr. Irving has given us such an excellent talk and we have signed him up for about this time next year too! Our April meeting will be concluded with a talk by Mr. Ted W. Macie, the International Business Machine Representative located in Aruba. He will talk on Industrial Electronics and cover such items as the Electronic Brain, The Memory Circuit, a Seventy-five Foot Blue-print, and Special Business Machines.

—Jim Lopez, Special Corr.

BOSTON

The Boston Section held its fifth meeting of the season at the Boston Yacht Club, Rowe's Wharf, Boston on February 23rd. Sixty members were present for dinner at 6:30 P.M. The speaker was Dr. W. N. Greer, Leeds & Northrup Co., whose lecture topic was "Measurement of pH and Conductivity."

The next meeting of the Boston Section will be held at the Hotel Statler, Boston on March 30th, when the American Meter Co. will be host to the members. Mr. W. G. Hamilton will speak on "Flow and Pressure Transmission."

—J. H. Condon, Corr.

CALIFORNIA

The March 1st meeting was preceeded by an afternoon tour through the Consolidated Engineering Corp. plant in Pasadena. Groups were conducted by members of the Consolidated Engineering staff and brief talks on the equipment presented in the various departments. A total of 119 members and guests attended the dinner meeting where the program was rounded out by prepared talks on Consolidated activities and equipment. Mr. Bob Smallman presented, "A Brief Orientation into the Field of Static and Dynamic Measurements and Recording." Mr. L. P. Robinson described, "A New Recording System for Static and Dynamic Measurements of Physical Quantities by Electrical Means."

Mr. W. D. Merrick outlined preparations for the April 8th joint meeting with the Inyokern Section. Transportation for the 145-mile trip to the all-day meeting was discussed and a full program of rocket launchings and demonstrations of equipment is planned in conjunction with a tour of the Naval Ordnance Test Station at Inyokern, China Lake.

—Chris Wagner, Corr.

CENTRAL INDIANA

The March 1st meeting was held in the Purdue University Extension, Indianapolis. A very interesting illustrated talk "Methods of Temperature Measurement and Control" was given by Mr. W. E. Ellsworth, who has been working with pyrometers and thermocouples for many years and is now the district manager for the Claud S. Gordon Co.

The April 5th meeting will be a field trip through the Rock Island Refining Corp., Indianapolis. Mr. Leon Stewart will conduct the tour and talk on "Refining Processes of the Oil Industry."

—E. E. Taylor, Corr.

CUMBERLAND

The January 26th meeting was held at the Cumberland Plant of the Celanese Corp. of America. The speakers were Mr. A. H. Shafer, Branch Manager and Mr. W. H. Young, Service Engineer, The Foxboro Co. Since compressed air was available, Mr. Shafer and Mr. Young were able to give a practical demonstration of the Model 40 Pressure Recording Stabilog Controller, M/41 Controller, Pneumatic Flow Transmitter and several other instruments. Quite a large part of the time was devoted to the calibration of the instruments and since it was a demonstration as well as a talk, the meeting proved very successful.

The February meeting was held on February 23rd, 1949 at the Algonquin Hotel. The speaker was Mr. C. A. Gates, Vice-President, assisted by Mr. A. W. Whittaker, District Manager, Wheelco Instrument Co. Mr. Gates gave a description and explanation of the oscillator and flag principle used in their Capacilog recorder-controller.

Our section is striving to invite each instrument company to speak so as to obtain a comparison of instruments available as well as learn valuable service information.

—G. W. Harrison, Corr.

GULF COAST

The Gulf Coast Section held its regular monthly meeting on March 2nd, at Lamar College, Beaumont, Texas, with 60 in attendance. Mr. C. B. Moore of the Moore Products Co. was the speaker for the evening. His subject was "The Problems of Process Control with the Pneumatic Null Balance Method." Mr. Moore's talk was illustrated with slides. An open discussion was held after the meeting with Mr. Moore answering many questions.

—J. W. Rutledge, Corr.

NEW JERSEY

The regular meeting held at the Essex House, Newark, New Jersey, on March 1st, was very well attended. More than 110 members and guests heard Mr. J. W. Graeb, Instrument Engineer, Engineering and Development Division, Imperial Oil Limited, Sarnia, Ontario, speak on "Unit Startups and What They Can Teach the Instrument Engineer."

The speaker pointed out that training for the instrument crew who are to operate the unit should include lectures on the process and instrumentation, manuals containing process diagrams, descriptions of each instrument on the unit and its function, as well as manufacturer's operating and maintenance instructions, and participation in the checking process so that each man is thoroughly familiar with the location and function of each instrument before the start-up.

Plans for the special meeting on April 5th have been completed. As previously announced, a "Symposium on Derivative Control Action" will be presented during afternoon and evening sessions by Messrs. V. V. Tivy, R. E. Clarridge, L. E. Jewett, and C. B. Moore. Preprints of the papers for this meeting will be available for those who attend. On Tuesday, May 3rd, Mr. H. Zeiboltz, Vice President of Askania Regulator Company will present an authoritative talk on "Hydraulic Governors." Both of these meetings will be held at the Essex House, Newark, New Jersey.

—W. A. HAGERBAUMER, Corr.

NEW YORK

The New York Section held its February meeting on the 28th at Mullins Cafe, 153 Chambers St., New York City. Mr. J. W. Bennett of Energy Control Co., Inc., delivered a very interesting talk on "Factors Affecting Automatic Control of a Modern Steam Generator." This was well illustrated with slides and many questions were discussed at the close of the paper. The following slate of officers were elected:

President—E. Ralph Manning
Vice-President—Charles E. Haggerty
Secretary—Norman J. Cherry
Treasurer—George Kauer, Jr.
Board of Directors—A. K. Joecks, S. G. Stemmer, H. R. Kalbfleisch, A. Lobert, H. Proske.

The March meeting will be held at Hotel Statler (formerly Hotel Pennsylvania) 33rd St. and Seventh Ave., Conference Room 2 at 7:30 P.M. Mr. A. B. Geuder, Sales Engineer of Hagan Corp. will speak on "A Discussion of Hagan Ring Balance Instruments."

—H. R. KALBFLEISCH, Corr.

NIAGARA FRONTIER

The regular monthly meeting was held on February 28th, at the New York State Institute of Applied Arts & Sciences in Buffalo. About fifty members attended the dinner immediately preceding the meeting, and an additional eight or ten arrived for the meeting only.

Mr. W. N. Greer of the Leeds & Northrup Co. gave an interesting talk entitled "Electrochemical Measurements in Industrial Processes." Mr. Greer indicated that a tremendous improvement had been made in the development for measuring the concentrations in solutions by the conductance method, particularly with regard to pH. As conductance is also a function of temperature, excellent temperature control can be obtained with the conductance method, particularly with alcohols.

—W. J. SOMMERS, Corr.

NORTHERN INDIANA

Saturday morning, March 12, about 25 men from the Northern Indiana Section and from the Whiting Instrument Men's Guild met at the State Line Generating Plant of the Commonwealth Edison System for an inspection trip through the plant. We were taken by Mr. Kramer, our host, to a classroom where he explained the workings of the system and told us high points of what we were going to see. The largest single generator in the world, steam lines that have been continuously under pressure for the last twenty years, and efficiency which is the highest in the Chicago area, were a few of the main points.

Most interesting to instrument men was a water column calibration device which is in use at the plant. The main features of this device are a 54 in. water column and a 30 in. mercury column arranged in parallel with a shut-off on the water column so that any differential up to 400 in. of water can be set up for testing flow meters.

This is the third field trip the Northern Indiana Section has had. Our first was to Michigan City where we were guests of Phil Sprague of the Hays Instrument Co. At the Standard Oil plant, we were entertained by Bill Thiesen and H. J. Stevenson. Mr. Kramer and Mr. Limbach were in charge of the trip through State Line Generating Plant.

—J. B. BECKMAN, Corr.

OAK RIDGE

The Section met March 2nd, at The Oak Terrace, Oak Ridge, Tenn. After dinner, when our regular business meeting began at 7:30 P.M., our hall was filled to capacity by members and guests. It was announced that the Executive Council had approved the applications for membership of seventeen men.

Mr. George Gritton won the ISA pin. We have a plan wherewith one member gets a pin each meeting night. This adds a little "zest" to the first part of our business meeting which is usually routine in nature. Mr. George Jamieson outlined his completed plans for sessions to discuss "Electronic Theory."

Our guest speaker was Dr. J. C. Mouzon, Director of Research, Brown Instrument Co., Philadelphia. His subject was entitled "Recording Electrometers."

Our next meeting will be on the first Wednesday of April. The main event of this meeting will be a talk on "Automatic Control" by a Taylor Instrument Co. representative. He will illustrate certain parts of this discussion by using an instrument installation which we will prearrange.

—JOHN H. CLARK, Sec'y

PHILADELPHIA

Our February 16th speaker, Mr. Albert W. Gabriel, Jr., Engineer, Westinghouse Electric Corp., Aviation Gas Turbine Division, talked on "Instrumentation of Turbo-Jet Engines." Reviewing the rapid progress made in the field of jet propulsion, Mr. Gabriel briefly outlined the operating principles of the newer engines and the conditions within a typical axial flow turbo-jet to provide a background for understanding the instrumentation problems involved.

Mr. Gabriel divided the instrumentation into three classes, namely: (1) for ground development testing, where any and all kinds are employed without regard as to size or personnel required; (2) for l development testing, where numerous but small, light, accurate, and automatic devices are required; and (3) for production models, where the instruments are kept to a minimum and must be direct reading as well as accurate and reliable.

Variables requiring measurement during all phases of testing include: the lubricating oil pressures and temperatures, the fuel pressures and rate of flow, bearing temperatures, engine rotor speed, and numerous values of internal air temperature, p sure, and velocity. Space limitations within the engine, excessive heat and noise inside the test cell, and extreme turbulence of air flow are some of the difficulties posed by these measurements.

Mr. Gabriel closed his enlightening talk with a look toward future instrument problems, now that the sonic barrier has been conquered. High altitudes will require compartment pressurization, instruments to check the low ambient pressures and temperatures. Supersonic flight, however, develops high surface temperatures on the airframe which must be countered by cooling systems with extensive instrumentation. Following the talk a technicolor film was shown of the McDonnell "Phantom" sea trials aboard an airplane carrier.

—W. E. HARRISON, Corr.

PITTSBURGH

On February 28th, after a short business period, including comments by Major Behar on his recent trip to Los Angeles, Mr. Samuel Feigenbaum of Jones & Laughlin Research Laboratories, spoke on "Temperature Measurement of the Open Hearth Bath." He explained the importance of this measurement to the operator, the metallurgist, and the instrument man. Two methods are now available for this measurement. In the thermocouple method, the platinum—platinum 10 per cent rhodium couple seems to be firmly established. Improvements in protecting tubes have been made, but maintenance costs are high on this type of equipment.

Radiation instruments are in use with both photocells and thermopiles. Some time was devoted to describing an immersion thermopile with air jet purging, which is used by Jones & Laughlin.

—M. M. FROMM, Corr.

PRESQUE ISLE

The March 22nd meeting is to consist of a very interesting tour through Koehler's Beer and Ale Co., located at 2131 State Street in Erie, Pa. The conducted tour is scheduled to begin at 7:45 P.M. and is to terminate at the Rathskeller.

On April 26th, at the Commons Room of Cannon College, the Section is to hear an illustrated lecture by Mr. Don Allshouse on "A History of Boiler Feed Water Regulation."

The last meeting this spring will be held on May 24th at the General Electric Community Center. We are greatly anticipating the return visit at this time of Dr. Steven J. Zand, Vice President of the Lord Manufacturing Co., who will talk on the timely subject of "Supersonic Aero-Dynamics." Dr. Zand, who spoke to our group last year, was recently honored by the United St ernment when he was presented "Award of Merit" for outstandi butions during the last war.

The success of open forums held sections of the Society was corrob our February 22nd dinner meetin Behrend Center, the Erie extension sylvania State College. Mr. Warren beck, of the Brown Instrument neapolis Honeywell Regulator Co open forum discussion on instru which brought forth many proble tion and unique suggestions. At meeting Mr. Howard Becker of the Electric Co. presented a very inte talk on the newly developed Ther

—H. F. RONDEAU, Corr.

ROCHESTER

The February 22nd meeting was held the Bausch and Lomb Physics Building of the University of Rochester. Mr. Henry Stoll, of the Taylor Instrument Companies spoke on "Fluid Flow Measurement" and covered the theory and operation of venturi tube, flow nozzle, orifice plate and pitot tube flow meters. The design and accuracy of response of each was thoroughly discussed as were certain possible sources of error.

Mr. Stoll's explanation of fluid flow in pipe lines and of the fact that it does not necessarily follow the square root law and his description of the new pitot-venturi measuring system brought forth a lively discussion and was enthusiastically received by the 55 members present. The following new officers started their year of service at this meeting:

Chairman: Mr. Irving G. McChesney
Vice Chairman: Mr. Norman Koenig
Secretary: Mr. Ralph C. Schwarz, Jr.
Treasurer. Mr. Charles W. Covey

—EINAR W. JENSEN, Corr.

ST. LOUIS

The March 2nd regular meeting on "Power System Telemetering" attracted the largest turnout of the year, when approximately 150 members and guests met in the Union Electric Company auditorium to hear Mr. Palmer T. Ramey, Communications Supervisor, describe the very complete and interesting installation.

Mr. Ramey began with a description of the operation of the Thermal Converter connected to each generator, which transforms power output to a direct current voltage. Output of various converters can be added and the total recorded on a load recorder calibrated in kilowatts, which also may integrate the power output. The recorder also acts as a transmitter, and sends out an electrical impulse of variable length, depending on the amount of power output. The generating stations in the vicinity of St. Louis, such as Venice, Cahokia and Ashley, transmit over telephone lines, while the distant ones at Bagnell Dam and Keokuk, Iowa, transmit over the power lines by carrier.

The primary purpose of power system telemetering is the most economical loading of plants. Additional benefits are greater speed of information to the load dispatcher in case of trouble, adding to the reliability of the power system. Following the talk the equipment in the load dispatcher's office was inspected.

—H. E. ZEFFREN, Corr.

SARNIA

The Section held its January 14th meeting in the New Moose Hall on South Mitton St. The meeting was opened, as is our established practice, with the showing of a film. Although the film, entitled "Brazing Flanges with Silver Solder" did not cover an art directly related to ours, it gave us an interesting insight into the intricacies involved in brazing large flanges to pipe. It would not appear to be the simplest of operations.

Mr. A. Upfold, the Electronics Technician in the Polymer Instrument Department, was introduced by Section President J. W. Graeb, as the speaker of the evening. He described the necessity for and demonstrated the techniques employed in trouble shooting electronic circuits in industrial type temperature recorders. It should be noted that this was the first of a series. Printed notes had been prepared and were distributed outlining common troubles, their symptoms and the corrective measures that should be taken. To ensure complete coverage of the membership, the notes were mailed to all members with the notices of the next meeting.

The meeting, Feb. 11th, opened with the showing of a very excellent film produced

(Continued on Page 358)

Some Problems *in the* Precise Measurement *of* Pressure*

By W. G. BROMBACHER
National Bureau of Standards

AMONG some scientists and engineers the erroneous idea exists that the field of pressure measuring instrumentation is a closed chapter; no really new developments are either required or in prospect. Even a casual search of engineering and scientific literature reveals a steady stream of articles on new or improved instruments for measuring pressure. Broadly speaking, this field may be held to include both indicating and recording instruments, remote indicating instruments, pressure regulators and controllers. Measurements may be made dynamically or statically. Only indicating instruments primarily for static use will be discussed in this article, although the discussion may have application to the other fields also.

The indicating instruments can be classified either by the type of pressure-sensitive element used or by the range of pressure to be measured. Since many designs are limited to a definite pressure range, it is convenient to use the latter classification. For the purposes in view here the following rather arbitrary classification is made:

I. Absolute pressure
(a) vacuum, below 1 mm. of mercury
(b) 0.5 to 800 mm. of mercury
(c) 1 to 3 atmospheres
(d) above 3 atmospheres

II. Differential pressures
(a) small differential pressures .001 to 1 mm. of mercury
(b) up to 100 inches of mercury
(c) high pressures 50 to 50,000 psi (commercially available)
(d) high pressures, 50,000 to 125,000 psi (under commercial development)
(e) high pressures, above 125,000 psi

In all of these categories there is need in some applications for greater precision and accuracy than can be obtained from instruments now available. In some cases greater convenience and reliability in operation are highly desirable.

For example, more reliability and greater convenience is desirable in vacuum gages, particularly for field use in meteorology and aeronautics in the range just below 1 or 2 mm. of mercury.

For measuring high vacuum an instrument as convenient and reliable as an aneroid barometer is in demand. To secure it invention seems necessary.

Also instruments for measuring absolute pressures and diffential pressures between 1 and 3 or 4 atmospheres are not available in the accuracy and convenience desired. Mercury columns can be designed to be sufficiently accurate, but the columns are inconveniently high for easy observation. The commercial demand seemingly does not yet warrant the development of accurate and sensitive aneroid type gages in this range.

For the balance of these introductory remarks, the discussion will be limited to three categories of precise measurement:—

(a) Measurement of absolute gas pressure in the range from 1 to 800mm. of mercury. (b) Measurement of small differential or gage pressures to high precision. (c) High pressure measurements in the range 100 to about 125,000 psi.

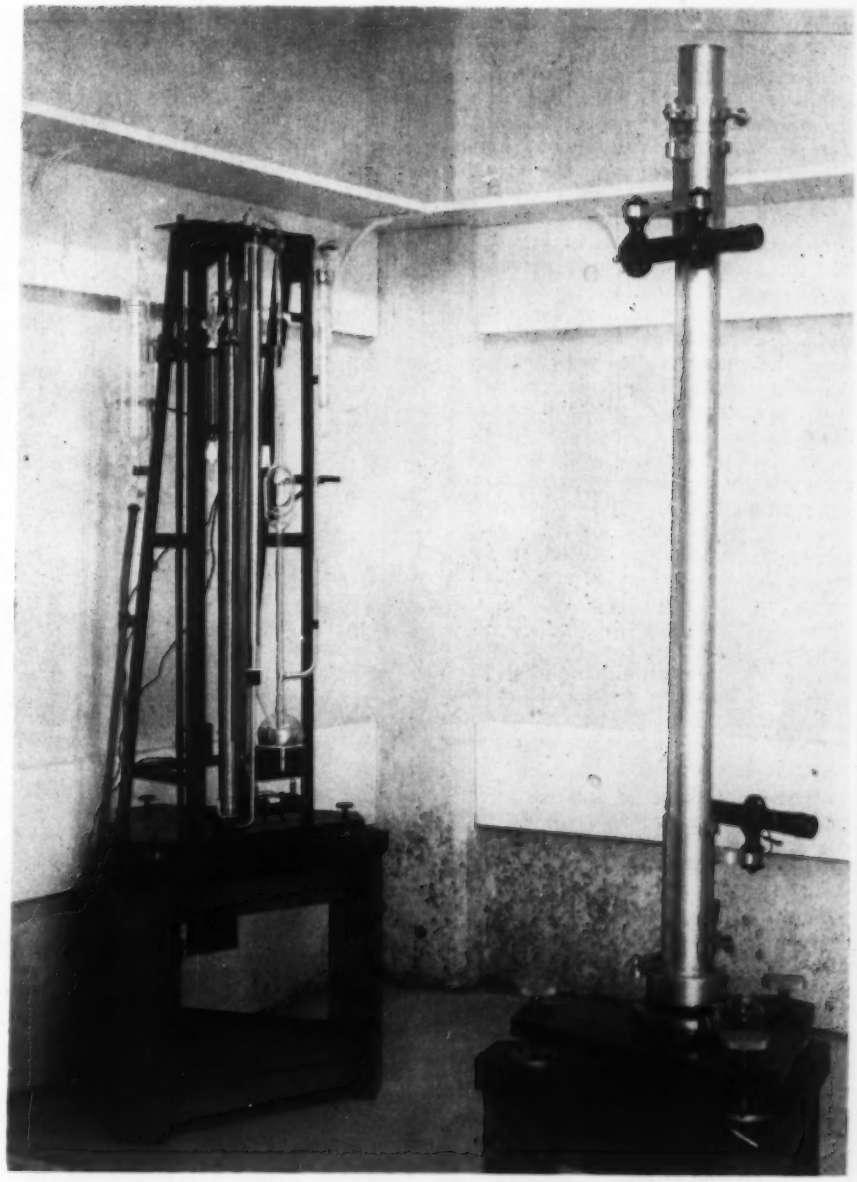

Fig. 1. Barometer used as a working standard in calibrating portable barometers.

Absolute Pressures

The instruments commonly used to measure absolute pressures in the range of interest are the mercurial barometer and the aneroid barometer. Contrary to opinions held by many engineers and scientists, the portable mercurial ba-

*Presented at the Second Annual New York Section Conference, January 28-29, 1949, Hotel Statler, New York, N. Y.

rometer is limited in accuracy to about 0.1 mm or 0.005 inch of mercury. This accuracy is obtained only if the bore of the tube is at least about 0.6 inch, to reduce capillary errors, and if the barometer temperature is controlled or accurately known well within 1 degree C at the higher pressures, with a greater uncertainty permissible at low pressures. Other factors, such as scale error, poor design, etc., may also introduce errors exceeding the above value.

A mercurial barometer used as a standard at the National Bureau of Standards in checking portable barometers at pressures down to about 1 mm of mercury may have application where an absolute accuracy of about 0.03 mm or .001 inch of mercury is required. This barometer is shown in Fig. 1. It consists of a U-tube, 0.8 inch bore, a diffusion pump for maintaining a vacuum above the mercury on one leg, and a McLeod gage for measuring this vacuum. The stainless steel scale, between the legs of the U-tube, is graduated in 0.5 mm steps from 0 to 800 mm and has been calibrated. The scale reading at the mercury levels is made by sighting through two telescopes which are mounted on a very rigid cathetometer equipped with levels and levelling screws. Each telescope has an eyepiece with a reticle used as a vernier with which the least reading is .02 mm. The whole assembly is mounted on a cork-concrete platform in a sub-basement room to obtain unusual mechanical stability. The room is thermostatted day and night at about 25 degrees C, with short time temperature variations less than .05 degrees C.

Corrections must be applied or considered for over 20 sources of error, many minute, if the stated accuracy is to be obtained. Note that by placing the scale in the plane of the mercury column instead of the cathetometer, the error introduced by a given angle of tilt of the telescope axis is greatly reduced.

This barometer is used principally in a closed system to which it and instruments under test are connected. Precise maintenance of the pressure at a desired value is essential in most work, for which purpose a barostat was developed. This holds pressures at a constancy within 0.01 mm of mercury during the time required for a reading (one to ten minutes).

The 100 degree C point on the International Temperature Scale is defined as the temperature of equilibrium between liquid water and its vapor at a pressure of one atmosphere. To match the precision with which temperature can be measured, realizing this standard experimentally, requires measuring absolute pressure to an accuracy at least ten times better than possible with the design of mercurial barometer described above.

A precision manometer for measuring absolute pressure has been designed

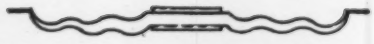

Fig. 2. Nesting corrugated diaphragm capsule.

and built at the National Bureau of Standards, which is briefly described in reference (1). This has a range from 0.2 to 2 atmospheres. At one atmosphere the column height can be measured to an accuracy of about a part in one million (about one micron). This accuracy is equivalent to temperature differences of less than 0.0001 degree C. In deriving pressure from the measurements the above accuracy may not be quite realized because the local value of gravity and the density of mercury are each probably uncertain to about ten parts in a million. To make the standard atmosphere independent of the density of mercury and of gravity, it has been defined, in the International Temperature Scale of 1948, as an absolute pressure of 1013250 dynes per sq cm. This corresponds to the pressure exerted by a mercury column 76 cm high, having a density of 13.5951 grams per cu cm and subject to a gravitational acceleration of 980.665 cm per second. It is hoped that this definition of the standard atmosphere will be adopted as an international standard for all scientific purposes. It should be added that other national physical laboratories have also constructed mercurial barometers of high precision.

Aneroid barometers, chiefly for use in meteorology and civil engineering, have been greatly improved in performance by several manufacturers during the last ten years. Illustrative of the progress made, one commercial aneroid barometer for measuring atmospheric pressure now at the National Bureau of Standards has a pointer tip deflection between 6 and 8 mm (one-fourth and five sixteenths inch) per mm of mercury with graduations every 0.2 mm of mercury. The range is from 71[illegible] to 787 mm of mercury. Its calibration has shifted less than 0.3 mm of mercury in six years. Available data indicate that the probable error of a single reading is plus or minus 0.05 mm of mercury, a performance not equalled by many mercurial barometers. This is not to say that all aneroid barometers of this design will necessarily have this performance.

The sensitivity of the short range aneroid barometers described above is not obtainable in long range barometers without considerable mechanical complication, nor can the above accuracy be approached in conventional designs. Hysteresis and drift effects are significantly larger. In the best quality aneroid barometers, the hysteresis effect approaches a minimum of 0.1 per cent of the range of pressure change and the drift effect of a rested barometer is about 0.2 percent of a sudden pressure change in the first hour after subjection to a large pressure change.

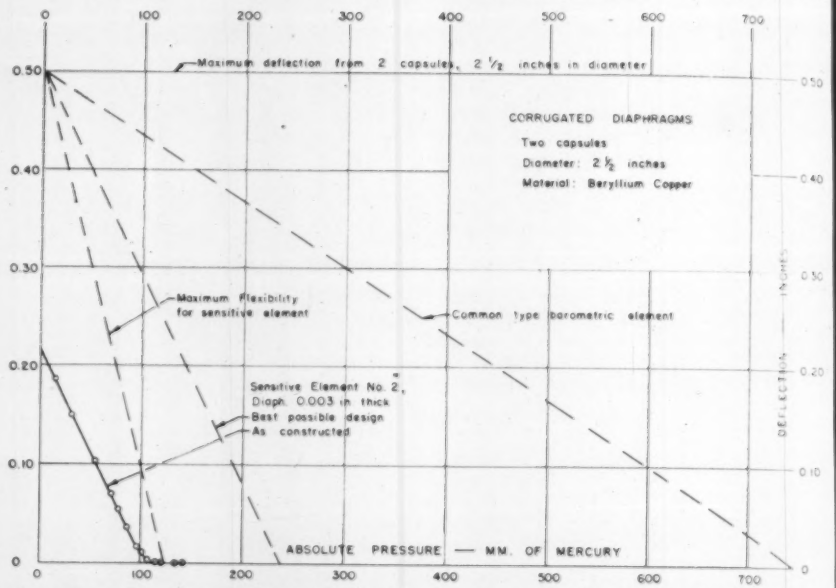

Fig. 3. Performance of one design of evacuated nesting diaphragm capsule. The deflection starts at about 120 mm of mercury, but could be designed to start at about 230 mm without loss of performance.

In order to obtain sensitivity at low absolute pressures without excessive mechanical multiplication of the deflection of the aneroid capsule, the use of a nesting capsule has been proposed (reference 2). This has been developed commercially for several applications (probably independently, since the idea itself is old).

The nesting capsule is shown in Fig. 2 and the performance for one design (reference 2) in Fig. 3. For use in an aneroid, the capsule is evacuated. As the evacuation proceeds the two diaphragms nest together, without further deflection, at some fraction of atmospheric pressure determined by the design. In use, no diaphragm deflection is secured until the ambient pressure is reduced to the pressure at which the diaphragms originally nested. In this element, diaphragms can be used which

have full deflection over the reduced pressure range without danger of overstressing them.

At present, absolute pressure gages with nesting diaphragms are available commercially where the pointer deflection and mechanical system are the same for selected ranges from 0 to 20 up to 0 to 250 mm of mercury. The instruments are convenient to use for measuring moderate vacuums. As now available, their accuracy is somewhat better than one percent. There is some hope that the nesting diaphragms can be utilized to dip further into the vacuum range, perhaps to obtain readings below one mm of mercury to the nearest 0.01 mm.

Small Differential Pressures

Micromanometers have been developed in a great variety of designs for various special applications. In the main these designs have depended upon some scheme for amplification of the change in liquid levels in the two legs of a manometer; to a lessor extent designs have been based on an elastic element. Very few designs are available commercially. Two recent ingenious developments in measuring small differential pressures, one of each type, will be described to illustrate the progress in this field being made by chemists in their efforts to measure low vapor pressures.

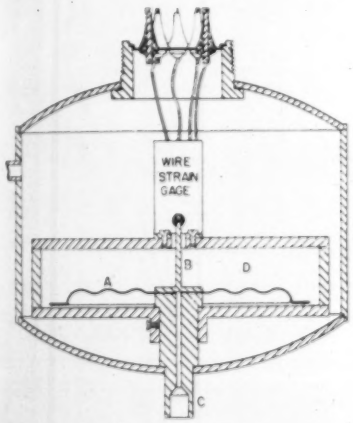

Fig. 4. Matheson-Eden manometer. A is the nesting diaphragm capsule; B, the connection to the wire strain gage; C, the inlet to, and the support for, the capsule; and D, airtight space except for opening E.

The Matheson-Eden manometer (reference 3) is shown schematically in Fig. 4. A nesting diaphragm capsule 3 inches in diameter is used as the pressure element. The central deflection of this element controls the stresses in an electrical resistance wire strain gage, the change in resistance of which is measured by a bridge circuit and a galvanometer. The stiffness of the strain gage is almost six times that of the capsule, so that the full potentialities of the latter are not realized. These strain gages are now available with less stiffness.

An idea of the sensitivity is obtained from Fig. 5. Individual curves are obtained for two values of current, 1 and 10 milliamperes, through the strain gage. The maximum sensitivity controlled by the maximum current in the strain gage, is of the order of 3 mm of galvanometer deflection per micron of mercury and could be increased by further amplification if the overall reliability justified it. The central deflection of the diaphragm capsule-strain gage unit is about 0.4 x 10^{-6} inch (10^{-5} mm.) per micron of pressure change. The capsule nests at a pressure of 0.5 mm. of mercury applied outside of the capsule.

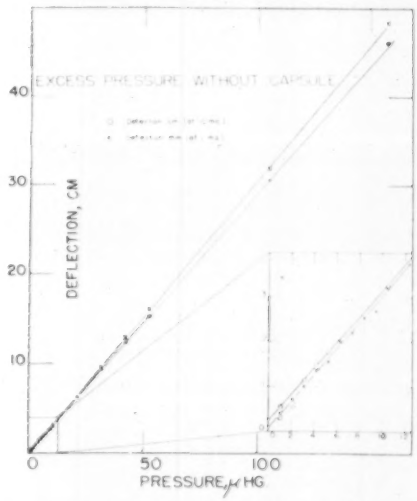

Fig. 5. Performance of Matheson-Eden manometer. The abscissa unit is in microns of mercury (0.001 mm of mercury). The outside of the capsule was subjected to the higher pressure.

Another instrument measuring small differential pressures is the Puddington manometer (reference 4). This is shown schematically in Fig. 6. The two legs, A & B, of the manometer are large (and equal) in cross section area compared to that of tube C, on which readings are made. To obtain a zero, valve H is shut when the pressures upon the mercury surfaces in A & B are equal. By air pressure applied at K, the mercury in B is forced to mark *G*, whereupon the mercury position in C is taken as zero. To make a measurement, a small pressure is applied at leg A, valve H is then closed, and again the mercury level in B is brought to mark G, determining a new position of the mercury level in C. The pressure is then determined by

$$L = \frac{1}{2}\,\frac{B}{C}\,P$$

Where

P is the pressure in mm. of mercury
B & C are the areas of tubes B and C
L is the length of the mercury column from the zero pressure position in mm.

In one actual instrument, the diameters A & B were 46 mm. and of C, 0.78 mm., which gave 1760 as the magnification factor one-half B/C. This gives a deflection L of 1.8 mm. per micron (0.001 mm. of mercury).

The readings of this manometer are affected by temperature changes, which must be kept small, and also perhaps by meniscus uncertainties. It is considered that the overall accuracies of the Matheson-Eden and the Puddington are of the same order. The former is more expensive to construct but has the advantage of giving continuous readings.

High Pressure

High pressure phenomena are becoming of widening interest to physicists, chemists and engineers. In engineering, pressures of 20 to 30,000 psi were, until recently, considered quite high; now the range of 100,000 psi is considered on the verge of being commonplace. At least three commercial organizations are now making equipment for producing pressures up to 100,000 psi. Of course, this pressure is low by comparison with those obtained in Professor Bridgman's laboratory at Harvard University or in the Geophysical Laboratory at Washington, D. C.

The piston gage, or dead weight tester, is commonly used as the working standard in checking other types of pressure gages such as the Bourdon tube gage or resistance wire type. The weights of the piston gage can be calibrated and the area of the piston measured, but the effective piston area is, in general, somewhat greater than the measured value and may vary with pressure because of cylinder distortion under load. The difficulty in determining the piston area accurately is seen

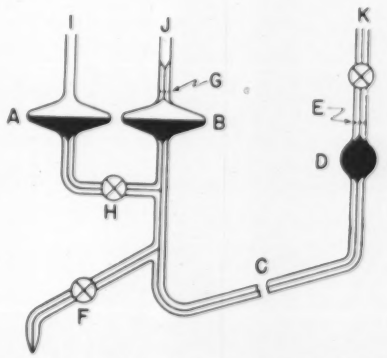

Fig. 6. Puddington manometer. A and B are the legs of the manometer; C is a long capillary tube; D, a storage volume; E and G are indices; and F and H are stopcocks.

more vividly if it is assumed that the weight limit for a 100,000 psi piston gage is 1000 pounds. It follows that the piston area is only 0.01 square inch.

The effective area of the piston of a piston gage used as a working standard usually rests ultimately upon a comparison with a mercury manometer. Since 40 or 50 feet is the practical limit to the height of a mercury column, producing a pressure difference of about 300 psi, it is easily seen that some scheme is required in order to extend the range to high pressures. Several schemes have been used. In one, the mercury manometer is designed to be subjected to high pressures, increasing by steps. Two piston gages are used,

one at the top of the mercury column and the other at the bottom; then their positions are reversed. The pressure is thus known step by step and the calibration of the piston gages obtained.

In the second scheme a number of mercury manometers in series is used, reference 5, in which the pressure difference can be determined from the sum of heights of the unbalanced columns. In principle the arrangement would permit greater pressure in calibrating two piston gages, but actually the manipulation is troublesome and the readings difficult to make.

At present the National Bureau of Standards tests piston gages for accuracy of the weights and to determine the effective area of the piston. The latter is computed from the results of a comparison test using a standard piston gage. The effective area of the piston of the National Bureau of Standards standard in the last analysis was determined up to 1000 psi from comparison tests against a mercury column, and up to 2000 psi using as a standard an experimental gage, constructed to have close clearances between the piston and cylinder. From about 2000 to 50,000 psi. the upper limit of the range, the calibration depends upon an extrapolation.

This situation offers no difficulty in testing Bourdon pressure gages since the accuracy in the extrapolated range is undoubtedly better than the ¼ percent claimed for the best quality Bourdon gage. For testing commercial piston gages below about 10,000 psi, the accuracy of the standard is estimated to be 1/10 percent or better; above this pressure no exact estimate of the accuracy can be made. In view of the gradual increase in the range of pressure of engineering interest, the range of 50,000 psi will be soon outmoded. Economy of effort indicates that at least one laboratory should be available to standardize pressure measuring instruments with considerable accuracy for investigators desiring this service.

In view of the situation just described, the Mechanical Instruments Section of the National Bureau of Standards is undertaking a program of developing standards for high pressure measurement which may at this time be summarized as follows:

(a) To design and construct piston gages to have minimum changes in calibration, due to distortion under load, to cover the range to 125,000 psi.

(b) To design and construct mercury manometers for calibrating piston gages possibly up to 30,000 psi.

(c) To design, construct and test portable pressure standards based on indications of volume changes associated with changes of state of certain liquids, notably water and mercury, under pressure.

(d) To design, construct and test portable pressure standards based on the vapor pressure of certain liquids at a selected temperature.

Under (c), Professor Bridman (reference 6) has found changes of state suitable for fixed points in a number of substances. Of particular interest is ice for which there are triple points near 30,000 at −22 degrees C, 50,000 at −17 degrees C and 90,000 psi at just above 0 degrees C. It is expected that volume changes will be used as the indicator, but the possibility of using other indicators, such as constancy of temperature, is not ruled out.

For a fixed point of pressure it is necessary that the change of state be conveniently observable and that the transition take place at a definite pressure which can be maintained constant for sufficient time to attain equilibrium and to make observations. The materials for the standards must be available in pure form, which limits the selection.

At present Dr. D. P. Johnson and C. H. Meyers at the National Bureau of Standards have work in progress on items (a), (b) and (d) of the program.

The convenience and utility of the Bourdon tube pressure gage is generally recognized. It is generally used where its accuracy and range are adequate. At present these gages are available to a claimed accuracy not exceeding one one-fourth percent of the range and in range up to about 50,000 psi. The situation indicates the need for further development, possibly of the accuracy, but particularly in the extension of the range.

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Section News

(Continued from Page 354)

by the L. S. Starrett Company, "The Tools and Rules for Precision Measuring." This film, dealing with precision measurements, stressed the importance of the care necessary if accuracy is desired. The section explaining the micrometer and vernier calipers were of value to the group since most of us, at one time or another, use these tools in the process of preparing flow measurement equipment-instruments and orifice installations, etc.

Maurice Smith the valve specialist in the Polymer Instrument Shop employed a number of valves, valve motors and valve trim sets to demonstrate troubles and cures, disassembly for purposes of servicing and reassembly procedures.

—GORDON M. CATCHPOLE, Corr.

SOUTHERN MICHIGAN

On March 16th, our program consisted of two talks given by Mr. Kenneth Urback and Mr. G. R. Wellman. Mr. Urback describing and discussing magnetic separators, pointed out several important uses of magnetic separator in processing goods for human consumption and the protection of plant equipment through the removal of "tramp iron" from material in process.

Mr. Wellman described a recent development in the metal detector field and demonstrated how all types of foreign bodies can be detected in various processing industries. His demonstration included a detailed description of the electronic circuits employed in the metal detector. The speakers appeared through the courtesy of Garrett Burgess, Inc. of Detroit, Michigan.

Mr. Glenn R. Miller of Battle Creek, Michigan was designated to represent the section at the Toronto meeting on May 14th. The next meeting of the section will be held on April 20th at Chicken Charlie's in Kalamazoo, Michigan.

—HOMER G. KUIPER, Sec'y.

WAYNE COUNTY

The February meeting was well attended. The points of most interest in the business meeting were the coming election of officers, a discussion of the course in Advanced Instrumentation now being held at the Rackham Building in Detroit, and plans for our annual trip through some industrial plant.

The Metrol Company of Detroit sponsored the program. Mr. Bruce Irwin of Hammel-Dahl Co. was the speaker. He gave a good talk with slides on control valves. We got a lot of useful information on materials and construction, valve packings, installations, etc., and saw illustrations of very high pressure and high temperature control jobs.

About twenty-five members and guests attended the March meeting. Appointment of a nominating committee for the coming election of officers was the most important item in the business meeting.

The DuBois-Webb Company of Detroit was the sponsor. Mr. Lyle Eige of Fisher Governor Co. was the guest speaker. There were slides and discussion on Magnaflux and X-Ray tests. Good and bad valve castings were shown. Other slides showed unbalance and stem torque in some designs of valves, rendering the extreme cases unworkable. A few slides gave valve characteristics.

At the April meeting the Foxboro Company will show an electronic analog demonstrating automatic control.

—JOHN MACPHERSON, Corr.

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SECTION SECRETARIES AND MEETING DATA

	Telephone	Date	Dinner	Meeting
Akron: Fred Appel, 932 Columbia Ct., Barberton, Ohio.				
Aruba: A. S. MacNutt, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.		1 Tues.	X	7:15
Atlanta: H. Kockritz, Fischer & Porter Co., 84 Peachtree St., Atlanta, Ga.		4 Mon.	X	7:30
Baltimore: Felix Cox, Bethlehem Steel Co., Sparrows Point, Md.		2 Fri.		
Boston: C. J. Nazzaro, 456 Central Avenue, Milton 87, Mass.		Last Wed.	6:00	7:00
California: D. D. Taylor, 234 E. Colorado, Pasadena 1, Calif.		1 Tues.	6:30	
Central Illinois: T. A. Carroll, 721 Hurlburt St., Peoria, Ill.		1 Wed.	6:30	7:30
Central Indiana: H. F. Coffey, 110 G Nelson Ave. Tyndall Towne, Indianapolis, Ind.		1 Tues.	X	7:30
Charleston: Albert H. Hix, 1529 B Dixie St., Charleston 1. W. Va.		1 Mon.	X	8:00
Chicago: Floyd E. Erstman, Rm 1420 Fisher Bldg., 343 S. Dearborn St., Chicago, Ill.		1 Mon.	6:30	8:00
Cincinnati: Smith Hickenlooper, 1147 Beverly Hills Dr., Cincinnati, Ohio.		3 Fri.	X	8:00
Cleveland: L. H. Waldrip, 3030 Euclid Ave., Cleveland, Ohio.		4 Wed.	6:30	8:00
Cumberland: Clyde Babst, P. O. Box 447, Cumberland, Md.		*Tues. after 4 Mon.*	6:30	8:00
Detroit: T. S. Cawthorne, 570 Maccabees Bldg., Detroit 2, Mich.		3 Tues.		
Eastern New York: Wm. J. Claffie, Winthrop-Stearns, Inc., 33 Riverside Ave., Rensselaer, N. Y.		1 Tues.	6:30	8:00
Gulf Coast: A. E. Bunn, 2237 North Street, Beaumont, Texas.		3 Tues.		
Houston: E. E. Kleir, 2518 S. Blvd., Houston 6, Texas.		Last Mon.	X	8:00
Invokern, China Lake, Calif.; A. G. DeBell, U.S. Naval Ordnance, Test Sta., China Lake, Calif.				
Kansas City: Lewell F. Spies, J. F. Pritchard & Co., 908 Grand Ave., Kansas City, Mo.		Last Tues.	6:30	7:30
Louisville: H. C. Scherffius, 980 Palarka Rd., Louisville, Ky.		4 Tues.	X	8:00
Montreal: F. S. McCarthy, Canadian Industries, Ltd., Box 10, Montreal, Quebec, Canada.				
New Jersey: W. D. Archibald, 605 Westminster Ave., Elizabeth 3, N. J.		1 Tues.	6:00	
New Orleans: W. H. Haney, 2927 Music Avenue, New Orleans, La.		*No Regular Date*		8:00
New York: Norman J. Cherry, Bristol Co., 250 W. 57th St., New York 19, New York.		Last Mon.	6:30	8:00
Niagara Frontier: K. J. Fees, RFD #1, Niagara Rd., Niagara Falls, N. Y.		4 Mon.	X	8:00
North Texas: F. Zapffe, Lone Star Gas Co., 2701 Logan St., Dallas 1, Texas				
Northern Indiana: C. P. Haynes, 935 177th Place, Hammond, Indiana.		3 Wed.	6:30	7:30
Oak Ridge: John H. Clark, 138 Clayton Hall, Oakridge, Tenn.		1 Wed.	7:00	
Ontario: John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada.		3 Thur.	6:45	
Philadelphia: C. W. Wood, 6908 Market St., Upper Darby, Pa.		3 Wed.	X	8:00
Pittsburgh: L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pittsburgh 13, Pa.		4 Mon.	6:30	8:00
Presque Isle: R. P. Marshall, 161 W. Main St., North East, Penna.		4 Tues.	X	8:00
Richland: R. S. Hammond, 402 Abbott, Richland, Washington.		2 Wed.	X	7:30
Rochester: R. C. Swartz, Jr., 1201 Granite Bldg., Rochester 4, New York.		3 Tues.	X	8:00
St. Louis: W. G. Lee, 4710 Delor St., St. Louis 16, Mo.		1 Wed.	X	8:00
Sarnia: C. G. Elder, 323 Maria St., Sarnia, Ont., Canada.		2nd & 4th Fri.	X	
South Bend: Charles E. Williams, 921 Lawndale Avenue, South Bend, Ind.		1 Thur.	6:30	7:30
South Michigan: Homer Kuiper, 2517 Hillsdale, Kalamazoo, Mich.		2 Wed.	6:30	8:00
South Texas: H. C. Givens, La Gloria Corp., P. O. 637 Falfurrias, Texas.		1 Tues.	X	7:30
Tennessee: L. W. Thayer, 1837 Oakwood Dr., Kingsport, Tenn.		*No Definite Night*	7:00	8:00
Tulsa: C. R. Horton, 8211 E. 7th, Tulsa, Oklahoma.		1 Mon.	X	7:30
Twin Cities: Ray Hooper, International Div. Minneapolis-Honeywell Reg. Co., 2753 Fourth Ave., Minneapolis 8, Minn.		4 Tues.	6:30	
Washington: Edwin G. Brown, c/o American Instrument Co., 8010-20 Georgia Avenue, Silver Spring, Md.		3 Mon.	X	7:30
Wayne County: R. L. Swenson, 1569 13th St., Wyandotte, Michigan.		3 Mon.	6:30	8:00

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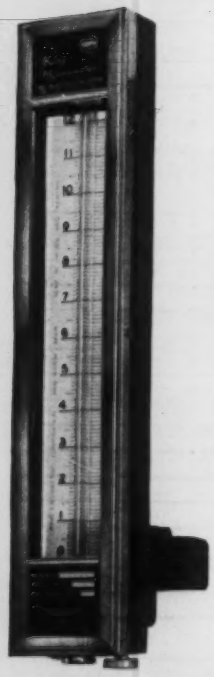

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MICRO ANALYSIS OF GASES

Continued from Page 321

RESULTS

Widely varying amounts of gases were evolved by this series of metals. Under the conditions of the tests, carbonized nickel-plated steel evolved by far the greatest amount of gas. Firing at 25 in. per min. at 1600 F. in cracked gas seemed to have little if any effect upon it and the gas evolution during the three steps of the test was erratic in both samples. Such an unusually large generation of gas would necessitate a longer break-down schedule than most cathode materials.

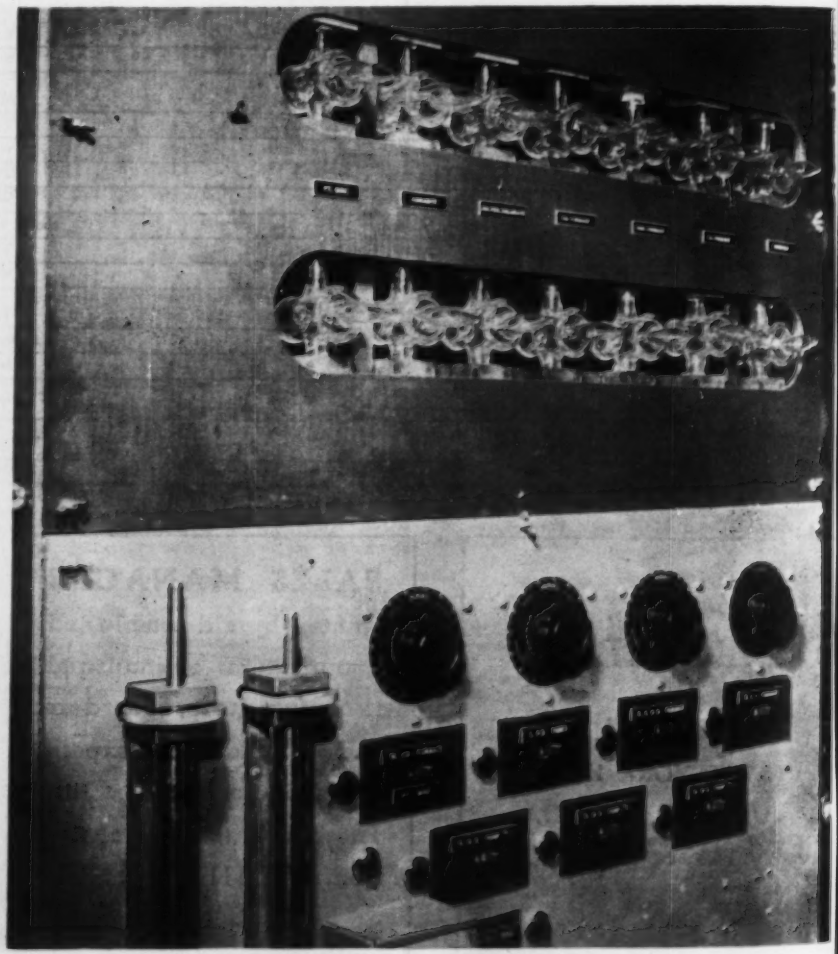
In sharp contrast to carbonized nickel, aluminized steel stood out for its very small evolution of gas during bombardment and life tests. Results from this steel indicated not only that a very short break-down schedule would be required to clean up the metal but also that process firing might be unnecessary. Plain steel gave relatively low results but only after being fired 8 in. per min. at 2050 F. in cracked gas.

In general, firing treatment did not change the gaseous properties of plain nickel or plain nickel-plated steel, but did improve the plain steel and oxidized nickel-plated steel. The carbonized nickel and blackened plain steel did not show the effect of firing until the life test (30 min. at 650 C.) when a decided improvement could be noted.

It can be concluded that previous firing cannot be regarded as a completely effective clean-up method. The type metal must be tested to determine the effect of the treatment.

The rapidity of gas evolution varies generally with processing of the metals. Theoretically the effect of firing the metals in a reducing atmosphere is to partly replace the gases in the metals by hydrogen. Hydrogen can be removed more easily by bombardment. The rate of evolution proved to be generally faster for the fired metals than the unfired. This indicates a partial replacement of the gases by hydrogen leading to more rapid evolution. The analysis of gas evolved during bombardment further indicates the role of hydrogen in more rapid degassing. Nearly all the samples undergoing a firing process have increased in hydrogen and decreased in nitrogen content. The CO_2-CO equilibrium is somewhat unpredictable owing to the processing of the metals. There was some indication of the presence of hydrocarbons which would be included as carbon monoxide in the analytical data.

The fact that 50.2 percent of the gas



Close-up of analytical section

TABLE IV

minutes at 650C.	*Gas volume cc.*
GROUP I	
Aluminized Steel	0.0029
Carbonized Nickel	0.0101
GROUP II	
Plain Steel	0.0698
Plain Ni-plated Steel	0.0724
Oxidized Ni-plated Steel	0.0795
Blackened Plain Steel	0.0834
Plain Nickel	0.0910
GROUP III	
Carbonized Ni-plated Steel	0.1510

olved from aluminized steel was hydrogen would account in part for the apid clean-up of this metal.

Based on results obtained during a 0-minute heating at 650 C. which represents roughly the amount of gas evolved uring the life of a vacuum tube, the etals can be separated into three distinct groups (Table IV). Aluminized teel and carbonized nickel after firing reatment are the best anodes. Carbonzed nickel is very poor and all others t into a middle group.

CONCLUSION

The utilization of a microgas analysis nit for study of the gas evolution of metals under vacuum can be considered n effective and practical method. Variation among different metals, and the ffect of processing these metals on the as evolution, can be quickly and accurately determined. Such tests obviate he need of pilot production of commerial variations of a particular metal or promising substitutes for that metal) until their value is positively established by microgas analysis.

For even broader applications, this ype of gas analysis may be used for etermining gas absorption or evolution f not only all types of metals but also lasses. For example, in the high-vacuum conditions existing in fluorescent amps or even the higher-pressure atmosphere of incandescent lamps, the volved gases from the glass bulb, the hosphors, or the tungsten may be easured. Similarly, the effectiveness f getters can be readily studied by uch a means. Thus, it is possible that many metals used for other purposes *nd in other fields* may justify a similar nvestigation. The increasing tendency owards higher purity of product and more exacting standards of technical erformance justifies and even necessitates the widespread adoption of such testing method.

Acknowledgments.—The authors wish o express their appreciation to Mr. R. L. Lambert for preparation of the metal samples and to Dr. E. F. Lowry nd members of the Sylvania engineering staff for assistance and advice during the development of the gas analysis nit.

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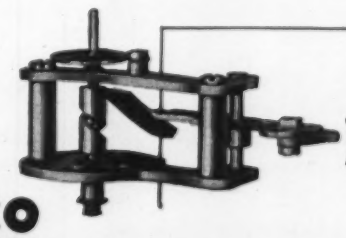

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TEMPERATURE CONTROL

Continued from Page 3

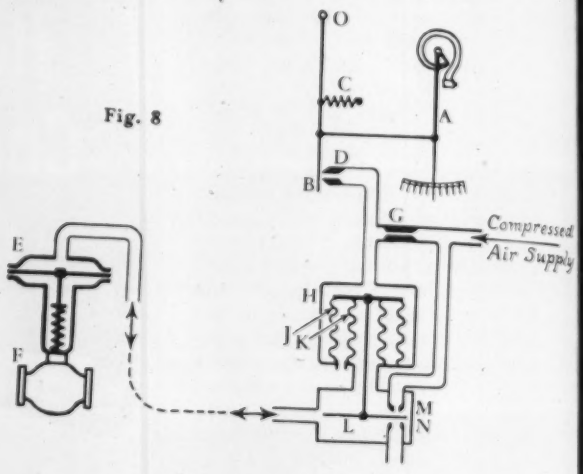
THE AMPLIFYING PILOT VALVE

The device just described has the inconvenience of sl reacti of the controlled valve which, to open completely, t ires exhaust of the air filling the tube connecting diaphrag E to controller, this exhaust taking place through nozzle D. we ha a relatively long connecting tube of a relatively larg diame as compared to that of nozzle D, we shall have a ve slow sponse of the controlled valve to a given temperature ch ge ins the heating unit and to the resulting alteration of t posit of pen A and of flapper B.

Another consequence is retarded controlled-valve a ion for practically instantaneous temperature controller action. We ha already seen the inconvenience of such a delayed valve action.

In actual practice, therefore, the discontinuous control device designed as shown in Fig. 8. It uses an amplifying pilot valve

Fig. 8



which comprises two concentric bellows J and K and a baffle closing more or less ports M and N connected respectively to t air supply and to the exhaust.

In this way, the movement of baffle L in one direction or in t other covers gradually one of these ports while it uncovers gradual the other and alters, therefore, the pressure existing after t baffle between the air supply pressure (when inlet port M completely uncovered and exhaust port N completely covered) a atmospheric pressure (when exhaust port N is completely u covered and inlet port M is completely covered), increasing decreasing this pressure according to the direction in which mov baffle L which is connected, in turn, to the joint surface of concen tric bellows J and K.

Atmospheric air is admitted between these bellows and t pressure after reducer G is exerted on the surface of the greate outer bellows J while the pressure after baffle L is exerted on t surface of the smaller inner bellows K. In this way, the pressur after reducer G has always to be counterbalanced by a highe pressure after baffle L, these pressures being in inverse proportio to the ratio of the areas of bellows J and K; therefore, pilot valve operates as a pressure-amplifying device.

This pilot valve—the operation of which corresponds thus to a amplified reproduction of the sudden or gradual changes of t pressure existing after reducer G—is used in discontinuous co trollers as well as in continuous controllers. We shall see now wha is the improvement insured by its use in the total-action discon tinuous temperature controller which we are presently studying.

In this case, as before, a decrease of the temperature inside th heating unit below the lower limit of control results in a smal movement to the left of pen A and flapper B against spring C and in a slight flow of air through nozzle D which, in turn, results in a sudden drop of pressure after reducer G down to atmospheri pressure.

This sudden drop of pressure exerted on the surface of the outer bellows J causes, in turn, a total rise of baffle L which, therefore covers completely inlet port M and uncovers completely exhaust

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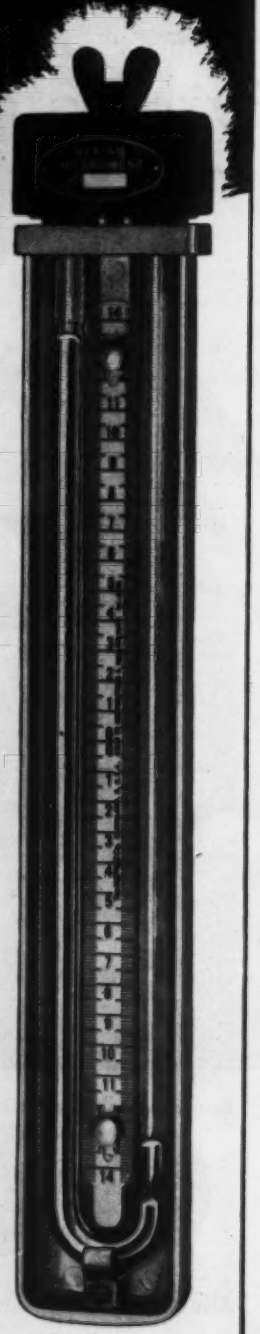
Honeywell *Advanced Instrumentation* FOR BETTER PROCESSING BROWN

A U-TYPE *Absolute* PRESSURE GAUGE BY MERIAM



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It is a U-tube manometer with one leg sealed and filled with mercury; the other open tube leg connects to the source of pressure to be measured. The tube is removable and can be easily replaced, when necessary, with another tube, mercury filled, shipped directly to location.

Of simple design—no cams, gears, levers—the Meriam U-Type Absolute Pressure Gauge is accurate and dependable. It is strongly built for lasting service. The gauge head fastens to the body by a single wing nut. Available in wall or flush front mounting styles. The wall mounted unit, illustrated, is Model C-1142 WM and is fully described in catalog sheet C-1142 WM—available upon request.

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MANOMETERS, METERS AND GAUGES FOR THE ACCURATE MEASUREMENT OF PRESSURES, VACUUMS AND FLOWS OF LIQUIDS AND GASES

port N; the pressure existing after baffle L and exer[t] on t[he] surface of inner bellows K becomes, therefore, also e[qual] to t[he] atmospheric pressure and, in this way, the tube con[nec]ting d[iaphragm] phragm E of controlled valve F to the pilot valve is now connect[ed] to the exhaust N.

As before, the air filling this pipe is exhausted but, in this ca[se] this exhaust is made through port N having a much greate[r] diameter than nozzle D and, therefore, much more swiftly th[rough] through the latter. The addition of amplifying pilot valve [G], therefore, insures much more swift operation of controlled valve [F]. It must be noted that, in practice, it is not the absolute movement of pen A which actuates flapper B but the relative movement of this pen with respect to a control-point setting-arm or "control index."

Thus it is possible to set at the desired value, by means of the control index, the average temperature which has to be maintained by the automatic controller. This average temperature is obtained in practice by maintaining the temperature inside the heating unit under control within two (high and low) limits of control, the neutral zone between which is (as we have already seen for continuous action controllers) inversely proportional to the sensitivity of the controller.

In what concerns this sensitivity, it is not adjustable in the just-described controllers but there exist quite a number of other discontinuous temperature controllers—among them some electrically-operated "On-off" thermostats used in domestic heating—in which the user may adjust to the desired extent not only the average temperature to be maintained but also the neutral zone between the high and low limits of control, i.e., the sensitivity.

The discontinuous controller which we have just described makes possible, as has already been shown, either "High-low" or "On-off" control, the controlled valve being provided or not with a by-pass allowing to insure, when it is closed, a given minimum flow of the heating medium. This controller does not allow, on the other hand, the third mode of discontinuous control, namely the "Successive Multiple-step Control."

(We shall not describe this last mode of control in the descriptive part of the present writing, as it applies more especially to electrically-operated than to air-operated instruments.)

We have already seen that discontinuous automatic temperature control is not advisable for heating units having a too-low heat inertia. The use of the above-described controller—the main inconvenience of which is its lack of flexibility—is therefore limited to cases in which the fictitious mass of the heating unit under control is very high, this fictitious mass serving, as we have already said, as a "heat-flywheel" which equalizes the temperature fluctuations inside this heating unit and which enables it to operate at two different rates almost without any transition from one to the other.

In all the other cases, a satisfactory automatic control of the temperature in a heating unit requires the use of continuous-action controllers, as otherwise this temperature may be subjected to excessive fluctuations resulting from an insufficient fictitious mass of the heating unit and from a lack of flexibility of the discontinuous controller.

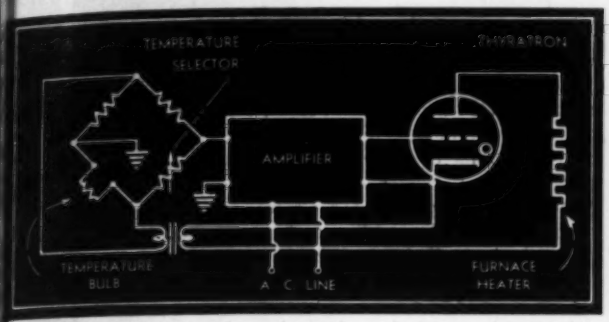
The first of the continuous automatic control methods which we studied theoretically is the Floating Continuous Control (function of time elapsed alone) and we have seen that this mode of control is involved in an incidental way in the operation of a discontinuous automatic control system when this system comprises a delayed action controlled valve or motor.

A NOTE ON THE FLOATING-TYPE CONTROLLERS

We shall not describe the practical way of designing a floating continuous automatic controller, firstly because this mode of control has (as we shall see later on), a fundamental inconvenience which limits its application to special cases, secondly because it applies mainly to electrically-operated instruments—just as does the Successive Multiple-step Discontinuous Control—and we have purposely limited the descriptive part of this essay to the description of air-operated automatic temperature controllers.

Nevertheless, it is possible to consider a hypothetical floating continuous automatic temperature controller in the very simple

MACDONALD
PROPORTIONING TEMPERATURE CONTROLLER



Range: Room temperature to 1000° F (special or higher ranges on request)
Controls Temperature Within: 0.1° F
Output Power (*available for furnace winding*):

	Type A	Type 18B
110 volt operation	225 watts	825 watts
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Type 18B — $375.00
Temperature Bulb for either model $40.00

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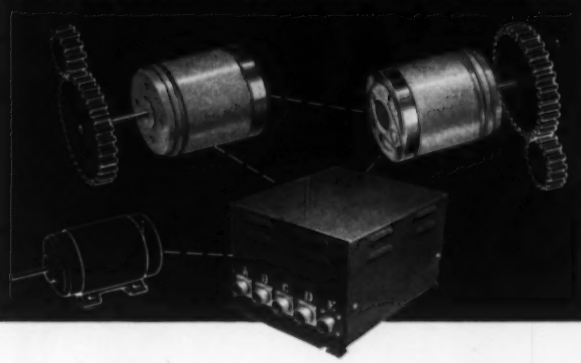

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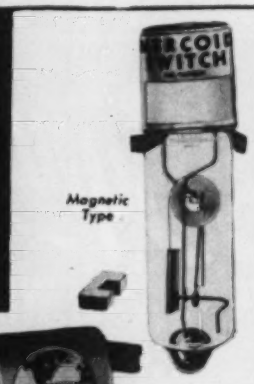

Magnetic Type

Tilting Type

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form of an indicating, recording or blind thermometer ing t electric contacts, the first of which is closed when the creasi temperature in the heating unit under control reaches e high limit of control and the second of which is closed when t decrea ing temperature reaches the lower limit of control; it herefo obvious that *both* of these contacts remain *open* when t tempe ature in the heating unit remains within the chosen limits f contr

The motor which operates the controlled valve is a eversib electric motor having two windings, each of which is co rolled b one of the contacts of the automatic temperature con oller. this way, an increase of the temperature in the heating nit und control above the higher limit of control results in closi the fir contact and in rotating the electric motor in a direc on whic closes the controlled valve; and a decrease of this tempera u below the lower limit of control results in closing the se ond co tact and in rotating the electric motor in a direction which ope the controlled valve.

It must be noted, first of all, that when the temperature in t heating unit is within the two chosen limits of control, both co tacts of the automatic controller remain open; the electric mot is stopped and the controlled valve is in *the last position* in whic it was at the end of the preceding change.

It must be noted, on the other hand, that the action of closing opening the controlled valve continues as an exclusive function the time elapsed from the moment when this closing or openi was started and that the rotation of the electric motor whic causes it is practically limited, in one direction or in the othe merely by the end-of-stroke contacts corresponding respectivel to the full or relative closing or opening of this controlled valve.

It is obvious, under these conditions, that if the result of th closing or opening of the controlled valve is not secured in sufficiently short time, i.e., if the decrease or increase of the hea input to the heating unit resulting from the alteration of th position of the controlled valve does not counterbalance in a suff ciently swift way the initial increase or decrease of the temperatu in the heating unit so as to bring again this temperature within th limits of control and thus stop the rotation of the electric moto the valve commanded by the latter will reach, in the meantime, on of its extreme positions and the whole system operate under dis continuous control—"On-off" or "High-low"—instead of operatin under floating continuous control.

Therefore, it will be understood that since the speed of th reactions of the heating unit depends mainly on its fictitious mass, th correct operation of floating continuous temperature controllers subjected to the condition of a sufficiently low fictitious mass this heating unit. We can say moreover, that if, as we have alread seen, a delayed action of the controlled valve can introduce floatin continuous control into discontinuous temperature control, a too swift action of this controlled valve can, conversely, transfor floating continuous temperature control into discontinuous contro

We can therefore conclude that, in a way opposite to that discontinuous controllers which are used on heating units havin a relatively high fictitious mass, floating continuous controllers ca be mainly used on heating units having a relatively low fictitiou mass; this condition limits their application and this is one of th reasons why we shall not discuss this mode of control in furthe detail.

To be continued.

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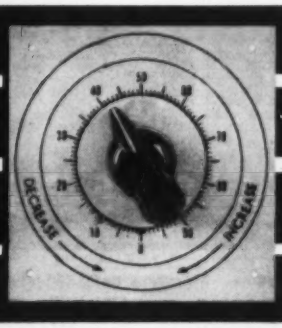

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Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 371.

R-166 COMBUSTIBLE GAS INSTRUMENT. 2-page Bulletin No. DT-4 illustrates and explains maker's "Explosilite" combustible gas instrument which continuously samples air of a working place, flashing alternate bright and dim red signal when flammable gas concentrations reach a predetermined danger point.—Mine Safety Appliances Co., Braddock, Thomas and Meade Streets, Pittsburgh 8, Penna.

R-167 LOGARITHMIC ATTENUATOR. 6-page folder describes and illustrates maker's "Model 510 Kay-Lab Logaten" logarithmic attenuator, a network of non-linear circuit elements adjusted to give an output voltage proportional to logarithm of input voltage. Applications, specifications are given.—Kalbfell Laboratories Inc., 1076 Morena Blvd., San Diego, Calif.

R-168 DIAL BORE GAGES. 4-page bulletin illustrates and describes maker's dial bore gages for larger bores, listing range extensions, uses, advantages, etc.—Nilsson Gage Co., Inc., Poughkeepsie, N. Y.

R-169 D.C.-A.C. CHOPPER. 4-page Catalog No. 232 describes and illustrates maker's "Type 222" chopper, a single-pole, double-throw, electro-mechanical chopper, rectifier (demodulator) or square-wave generator. Listed are advantages, specifications, price lists, etc.—Stevens-Arnold Inc., 22 Elkins St., South Boston 27, Mass.

R-170 RESET MAGNETIC COUNTERS. 2-page Bulletin G47-59A describes and illustrates maker's reset magnetic counter for A.c. only. Actuated through electromagnets, counters can be connected in series with any device having a contact arrangement. Bulletin G47-59B illustrates maker's reset magnetic counter for D.c. only. For connection to dry cells, storage battery, or D.c. current in series with any device having a contacting arrangement.—Veeder-Root Inc., 25 Sargent St., Hartford, Conn.

R-171 ELECTRIC CONTROL DEVICES. 250-page catalog presents descriptions, illustrations, prices, features, and other information on maker's electric control devices; contains sections on resistors, rheostats, relays, d-c. control, and miscellaneous.—Ward Leonard Electric Co., 31 South Street, Mt. Vernon, N. Y.

R-172 MICROMETER ADAPTERS. 4-page pocket-size folder illustrates and describes maker's "Microdapters" which attach to outside micrometers enabling them to measure inside dimensions. —Rimat Machine Tool Co., 1117 Air Way, Glendale 1, Calif.

R-173 PHOTOGRAPHIC PLATES. 48-page sixth edition of booklet contains information on photographic plates for scientific and technical use. Includes discussion on sensitometric characteristics of photographic plates, classification of plates, ultraviolet and blue sensitivity, panchromatic and other sensitivity, etc.—Eastman Kodak Co., Rochester 4, N. Y.

R-174 VACUUM-TUBE MILLIVOLTMETER. 2-page bulletin describes and illustrates maker's "Model MV-17A" d-c. vacuum-tube millivoltmeter, listing features, applications, specifications, etc.—Millivac Instruments, P. O. Box 3027, New Haven, Conn.

R-175 SCIENTIFIC GLASS PRODUCTS. 2-page Bulletin 10 describes and illustrates maker's heat-absorbing glass, clear Pyrex heat-resistant glass, color glass filters, quartz, etc.—E. S. Scientific Glass Products Co., Div. of E. & S. Optical Co., 911 Willow Ave., Hoboken, N. J.

R-176 "CURRENT DATA ON HIGH-VACUUM APPARATUS." 8-page Winter 1949 issue of this house organ contains article titled: "The Measurement of Low Pressures," and other information on current developments in the field of high vacuum.—Distillation Products, Inc., [illegible] Ridge Road West, Rochester 13, N. Y.

R-177 VISCOSITY TUBES. 12-page bulletin describes maker's viscosity tubes of heavy construction, of either bronze or stainless steel. Model numbers with specifications and prices are listed. Also describes vapor-pressure bombs, grease-testing apparatus, and penetration needles.—Koehler Instrument Co., 168-56 Douglas Ave., Jamaica [illegible] N. Y.

R-178 "SCIENTIFIC APPARATUS AND METHODS." 28-page Winter 1948-1949 issue of this house organ contains articles on phase microscopy, analysis with a mercury cathode, the polarography of lead, etc.; also section on scientific apparatus which illustrates and describes new and reinstated items, etc.—E. H. Sargent and Co., 155-165 East Superior St., Chicago 11, Ill.

R-179 PNEUMATIC DEVICES. 12-page Bulletin CL-15 describes and illustrates maker's "Controlled-Air-Power" devices which replace repetitive manual operations. Bulletin lists operations being done by devices, explains various models, etc.—Bellows Co., 222 West Market St., Akron, Ohio.

R-180 TESTING MACHINES. 4-page Bulletin M describes operation and illustrates parts of maker's "multi-low-range" universal tester for testing paper, thread, fabrics, plastics, springs, film, leather, bakelite, etc.—W. C. Dillon & Co., Inc., 5410 W. Harrison St., Chicago 44, Ill.

R-181 DIAL INDICATING HANDWHEELS. 8-page Catalog G illustrates and describes various models of maker's "Tejax" valve position indicators which show exact readings in turns and fractions of turns, and may replace regular valve handwheels. Also pictures and explains various models of "Tejax" dial-indicating handwheels for regulating and positioning equipment controlled by means of rotary or screw motion. Specifications are listed.—Tejax Engineering Corp., Box 1134, Providence, R. I.

R-182 REFERENCE GUIDE FOR MINIATURE ELECTRON TUBES. 6-page folder gives pertinent characteristics, data, and basing diagrams for all miniature tubes announced to date, regardless of make. Also indicates similar larger prototypes.—Hytron Radio and Electronics Corp., [illegible] Lafayette St., Salem, Mass.

R-183 HIGH-PRESSURE VALVES AND FITTINGS. 32-page Catalog 100 illustrates and describes maker's new "Speed Valve" with operating pressures up to 6000 psi, for fast assembly of high pressure set-ups. No threading or beveling of tubing necessary. Also describes ball bearing valves, combination valves, series valves, metering valves, high-pressure stainless steel valves and fittings up to 100,000 psi. Specifications, features are listed.—Autoclave Engineers, Inc., P. O. Box 1027, Erie, Penna.

R-184 PUSH-PULL CONTROLS. 4-page bulletin describes and shows diagrams of maker's "Tru-Lay" push-pull controls for transmitting motion between two fixed points, where one or both may be changing relative position. Standard assembly, anchorage, capacity, etc., are discussed. —Automotive and Aircraft Div., American Chain & Cable Co., Inc., 6-235 General Motors Bldg., Detroit 2, Mich.

R-185 "BURRELL ANNOUNCER." 16-page No. 49-1-33 issue of this house organ contains article titled: "Pure Water by Ion Exchange," explains and pictures various scientific laboratory instruments and equipment.—Burrell Technical Supply Co., 1942 Fifth Ave., Pittsburgh, Penna.

R-186 "EBERBACH ANNOUNCER." 16-page No. 49-1-33 issue of this house organ contains article titled: "Pure Water by Ion Exchange," explains and pictures various scientific laboratory

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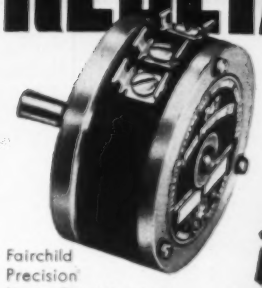

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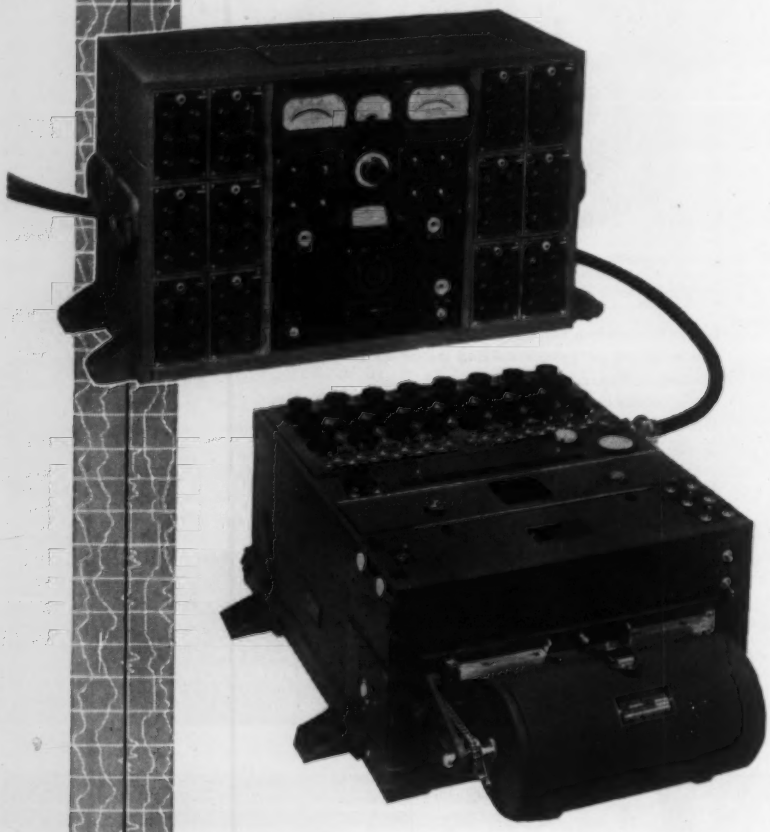

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instruments and equipment.—Eb[illegible]ch & Co., Ann Arbor, Mich.

R-187 AUTOMATIC BLUEPRI[illegible]TING CHINE. 6-page folder describes [illegible] maker's "Revolute M4" machine [illegible] production of blueprints, white[illegible]s, van prints, blueline prints. Specificat[illegible]s, elect data, features, etc., are discus[illegible]—Para Revolute Corp., Rochester 4, N. Y.

R-188 ETCHED-STEM THERMO[illegible]ETERS. page Catalog T-200 illustrates and [illegible]scribes er's etched-stem thermometers for [illegible]ious te operations. Test design, scale r[illegible]e, dia length, etc., are listed for each [illegible]odel.— Ready Thermometer Co., 1118 Bedford [illegible] Brooklyn 5, N. Y.

R-189 "GENERAL RADIO EXPERIMENTE 8-page Vol. 23 No. 9 issue of this house o presents articles titled: "A Crystal Indicat "The Versatile Voltage-divider." General R Co., 275 Massachusetts Ave., Cambridge 39, M

R-190 "THE CAPACITOR." 16-page Vol. No. 2 issue of this house organ contains ar titled: "A.C. Bridges," and section for bu sellers, and swappers.—Cornell-Dubilier Ele Corp., Hamilton Blvd., South Plainfield, N.

R-191 ELECTROPHOTOMETER. 8-page b tin describes and illustrates maker's electro tometer instrument for colorimetric analysis. eration, specifications, features, etc., are discus —Fisher Scientific Co., 717 Forbes St., Pittsbu (19), Penna.

R-192 HIGH-VOLTAGE RELAYS. 4-page Section 1500 illustrates and describes various t of maker's "custom-built" high-voltage rel Ordering information, etc., included.—Struth Dunn, Inc., 150 N. 13th St., Philadelphia Penna.

R-193 "THE OSCILLOGRAPHER." 16-p Vol. 11, No. 1 issue of this house organ pres articles titled: "The DuMont Type 250 Cath ray Oscillographers," "On Improving the formance of the Types 248 and 248A Osci graphers," and others.—Allen B. DuMont Labo tories, Inc., Instrument Div., 1000 Main A Clifton, N. J.

R-194 SOUND-LEVEL METER. 2-page bull describes and illustrates maker's sound-level me which feature: light weight, compact design, m ASA requirements. Specifications and design "pocket size" instrument are also discussed Herman Hosmer Scott, Inc., 385 Putnam A Cambridge 39, Mass.

R-195 CENTRIFUGES. 140-page catalog il trates and describes maker's micro, clinical, ch ical, serum, refrigerated, oil-testing, soil, other centrifuges. Contains theoretical and p tical information about centrifuges. Also microtomes, and bottle shakers. — Internati Equipment Co., 1248 Soldiers Field Road, Bo 35, Mass.

R-196 CHUCK JAWS. 4-page Bulletin B5-1 explains and illustrates maker's method of ma chuck jaws, giving typical examples.—Cerro Pasco Copper Corp., 40 Wall St., New York N. Y.

R-197 "TRACERLOG." 12-page No. 16 i of this house organ contains articles of gen interest to those in the field of radioactivity, descriptions of maker's equipment.—Tracer Inc., 55 Oliver St., Boston 10, Mass.

R-198 MULTI-TESTERS. 4-page bulletin il trates and describes maker's "Model 30" mu tester, covering 21 ranges. Also pictures and scribes "Model 300" signal generator; "Mo 10-P," a nine in one instrument covering ranges; "Model 10" range master covering range as 10-P. Features, ranges, prices, etc., cussed.—Bradshaw Instrument Co., 348 Liv ston St., Brooklyn 17, N. Y.

R-199 "BIDDLE INSTRUMENT NEWS." page Vol. 5, No. 1 issue of this house or describes equipment made by company, pres discussions titled: "How Temperature Af Insulation," and "Why Measure Speeds?"—Ja G. Biddle Co., 1316 Arch St., Phila. 7, Penna

R-200 MULTI-POINTER GAGES. 8-page Bu tin No. 163-B describes and illustrates latest velopments in maker's multi-pointer gages; plains use of diaphragm-operated unit for me urement of pressure, draft, or differential; some of standard ranges available; describes styles of casings.—Bailey Meter Co., 1050 Ivan Road, Cleveland 10, Ohio.

R-201 U-MANOMETERS. 2-page Bulletin 100 describes and illustrates maker's "Longli

pometer for pressure or vacuum. Basic prin- pressure ranges, construction, features, etc., scussed.—Gorrell & Gorrell, Haworth, N. J.

02 ELECTRIC COUNTER. 2-page bulletin bes and illustrates maker's "Type NR" high- electric counter for automatic high-speed ing with local or remote control by electric ctronic impulses. Ratings and prices, actuat- switch requirements, applications, etc., dis- .—Gorrell & Gorrell, Haworth, N. J.

03 COUNTERS. 6-page folder describes and ates maker's "Productimeters" counters for , rotary, lineal, and other applications. De- features, typical applications, and uses are sed.—Durant Mfg. Co., Inc., 375 Fairfield Stamford, Conn.

04 "CURRENTLY." 4-page Vol. II, issue his house organ contains discussions on versa- of "nobatrons," and three-phase regulators. ensen & Co., Inc., 375 Fairfield Ave., Stam- Conn.

CORRECTION

name of the maker of the TIME ESCAPE- T MOVEMENT described on page 184, ary issue, should be "Precision Products, 516 S. Lansing Ave., Tulsa 5, Oklahoma" than "Grayson Controls Div., Robertshaw- Controls Co."

05 AERONAUTICAL INSTRUMENTS. 26- booklet presents illustrations of, and de- s maker's G-load indicators; servo analyzers; precision angular pick-off; synchronous 16 camera; propeller speed governor. Features rices are listed.—Flight Research Engineering P. O. Box 1-F, Richmond 1, Conn.

06 "INSTRUMENT NOTES." 4-page No. e of this house organ presents article titled: id Filled Pressure Gage Systems."—Sta- Laboratories, 9328 Santa Monica Blvd., ly Hills, Calif.

07 LABORATORY PLANNING. 16-page et titled "Procedure in the Planning and rement of Laboratory Facilities" presents -points" and suggestions concerning plans he building of laboratories. — Laboratory ment Section, Scientific Apparatus Maker's ., Twenty North Wacker Drive, Chicago 6,

08 TUBE TESTERS. 4-page folder describes illustrates maker's latest complete line of ic mutual conductance tube testers. Covers er, portable and display models, listing fea- etc.—Hickock Electrical Instrument Co., Dupont Ave., Cleveland 8, Ohio.

09 SOLID ADSORPTION DRYING. 32- booklet titled "Because Water Isn't Pink" partial record of what various industries ing with maker's equipment to solve drying ems. Intended for non-technical as well as cally trained readers.—Pittsburgh Lectro- Corp., P. O. Box 1766, Pittsburgh 30, Penna.

10 ELECTRIC AND MECHANICAL FLOW ERS. 8-page Bulletin 800 describes and illus- maker's various steps in the production of c and mechanical flow meters.—Penn In- al Instrument Corp., 3116 North Seventeenth Philadelphia 32, Penna.

11 PANEL INSTRUMENTS. 2-page bulle- llustrates and describes maker's hermetically panel instruments supplied in voltmeters, ters, milliammeters, microammeters, and eters, etc., for a.c. and d.c. Another 2- bulletin describes and illustrates maker's 250 e meter in five and one-half in. diameter ith 8.7 scale length for additional reada-

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